DOT/FAA/ND410-97/1
DOT-VNTSC-FAA-97-14

Office of
Communications,
Navigation and
Surveillance Systems
Terminal Surveillance
Product Team
Washington, DC 20590

Low-Cost ASDE Evaluation Report: Raytheon ASDE (Phase II) Radar at MKE (M3625 / 18CPX-12)

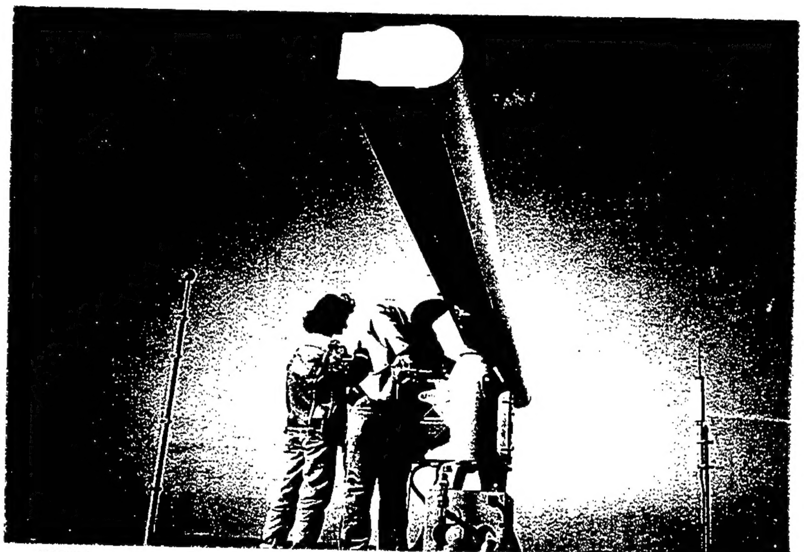
Research and
Special Programs
Administration
Volpe National
Transportation Systems Center
Cambridge, MA 02142-1093

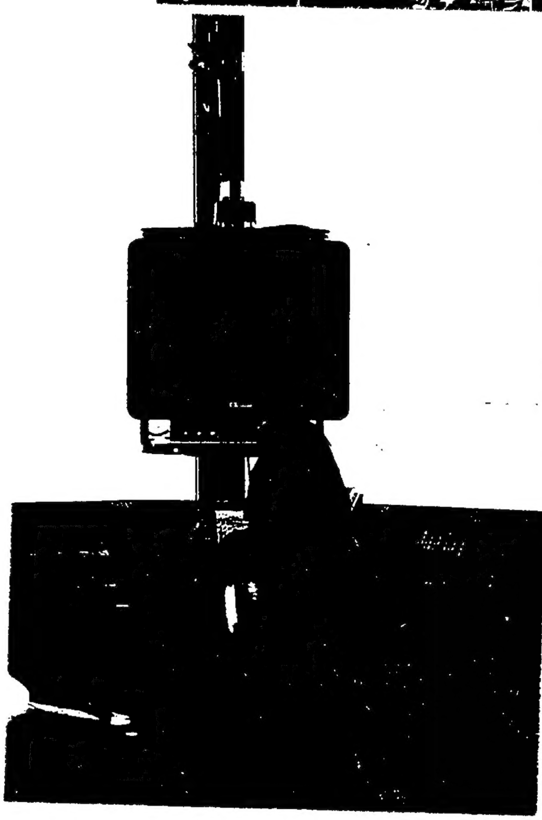
Final Report
September 1997

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Low-Cost ASDE Evaluation Report: Raytheon ASDE (Phase II) Radar at MKE (M3625 / 18CPX-12)





REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE September 1997	3. REPORT TYPE AND DATES COVERED Final Report September 1996 - March 1997

4. TITLE AND SUBTITLE
Low-Cost ASDE Evaluation Report: Raytheon ASDE (Phase II) Radar at MKE (M3625/18 CPX-12)

5. FUNDING NUMBERS
FA7P8/A7054

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Research and Special Programs Administration
John A. Volpe National Transportation Systems Center
Cambridge, MA 02142-1093

8. PERFORMING ORGANIZATION REPORT NUMBER
DOT-VNTSC-FAA-97-14

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Federal Aviation Administration
Office of Communications, Navigation and Surveillance Systems
Terminal Surveillance Product Team/AND-410
800 Independence Avenue, SW
Washington, DC 20591

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
DOT/FAA/ND410-97/1

11. SUPPLEMENTARY NOTES
[2]TAMSCO, [2]NATCA, [3]SRC, [4]JIL

12a. DISTRIBUTION/AVAILABILITY STATEMENT
This document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
The Federal Aviation Administration's (FAA) Runway Incursion Reduction Program's Terminal Surveillance Product Team (AND-410) has tasked the John A. Volpe National Transportation Systems Center (Volpe Center) to install and evaluate low-cost Airport Surface Detection Equipment (ASDE) radar systems to aid air traffic controllers, during low visibility conditions, to detect surface radar targets and sequence aircraft movement on active runways. This document publishes test results of the Raytheon ASDE installed at Milwaukee's General Mitchell Airport. The low-cost radars are being assessed for their ground surveillance potential for widespread use at smaller facilities. The report includes radar components and specifications, installation summary, functional and operational evaluations, system performance analysis, and recommendations. Test results show that, in low visibility conditions, the system enhanced controllers' situational awareness, detected and displayed targets, aided movement area clearance, and enabled controllers to confirm pilot's reported positions on the surface and their compliance with tower instructions. The ASDE's positive initial accceptance and low cost make it a sound option for small airports seeking effective ground surveillance radar.

14. SUBJECT TERMS
Airport Surface Detection Equipment (ASDE), ASDE-3, ASDE, radar, Phase I system, Phase II system

15. NUMBER OF PAGES
186

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

PREFACE

The Federal Aviation Administration (FAA) Runway Incursion Reduction Program's Terminal Surveillance Product Team (AND-410) tasked the John A. Volpe National Transportation Systems Center (Volpe Center) to evaluate low-cost alternatives to the ASDE-3–the surface surveillance radar system being installed at five major US airports by the year 2000–and to identify a radar suitable for smaller airports nationwide. This report, the second of a series prepared by the FAA's evaluation team, describes a Commercial-Off-the-Shelf (COTS) Raytheon ASDE radar (a scaled-down version of one used at Bombay International Airport) and gives the results of tests made on this system, as Phase II at General Mitchell International Airport (MKE) in Milwaukee, WI.

A team is only as good as its members, and the Volpe Center again extends thanks to the many people and organizations involved in the effort: the MKE staff for their cooperation and enthusiasm, especially the Air Traffic Controllers; MKE SSC Radar and Environmental specialties; Jayne Blasier of NATCA for excellent test coordination and participation; test controllers Steve Davis, Ray Zemel, and Dave Randolph; TAMSCO (with an assist from Ideal Helicopter) for a swift and efficient installation; System Resources Corporation; and EG&G Dynatrend/Camber Corporation for exhaustive test and documentation support.

Thanks go to the pilots in the test planes–the Phillip Morris crew who manned the Hawker Siddleys and to John Marinaro who flew the Cessna.

Thanks also to Raytheon for permission to use equipment drawings in Section 1, to Ken Baker of TAMSCO for his photos, and to the Jeppesen / Sanderson Corp. for their recently updated MKE airport map.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectare (ha) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gm)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

°C=5/9(°F - 32)

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

°F=9/5(°C) + 32

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0			1		2			3		4			5
CENTIMETERS	0	1	2	3	4	5	6	7	8	9	10	11	12	13

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

Updated 8/1/96

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The National Transportation Safety Board (NTSB) has identified the prevention of runway incursions as a high priority safety issue in the National Airspace System. Approximately 200 runway incursions occur each year on airports with control towers—about 70 involving air carriers—and several serious accidents involving loss of life have occurred. NTSB recommendation A-91-30 directly addresses the needs to improve ground safety at airports with high numbers of runway incursions and recommends the pursuit of low-cost solutions.

The Federal Aviation Administration (FAA) is responding by examining the series of technology options as defined in its System Engineering Management Plan for Runway Incursion Reduction Program (RIRP). The FAA is researching Non-Developmental Items (NDI) and Commercial Off-the-Shelf (COTS) technology for integration into the RIRP architecture. RIRP will provide air traffic controllers, pilots, and surface vehicle operators with real-time surface surveillance data. Use of this data will improve situational awareness of airport surface traffic for the many airport users and operators.

At the heart of RIRP architecture is a system which will collect, intelligently fuse, and distribute data from a host of existing and planned surveillance resources. The Airport Surface Detection Equipment (ASDE-3) radar system is the primary RIRP sensor for detection of non-cooperative airport surface vehicles. Though thirty-five major US airports will have ASDE-3 systems by the year 2000, its high cost ($7m) precludes it as a solution for lower level airports.

In 1994, the FAA assembled a Surface Products Team to test several available low-cost ASDE systems for viability as primary RIRP sensors for non-ASDE-3 airports. The first low-cost solution was a COTS radar manufactured by Raytheon Marine of Manchester, NH. The $100k equipment cost of the ARPA M3450 / 18CPX-19 included Air Traffic/Airways Facilities (AT / AF) operator and maintenance training, a 1-year maintenance warranty, and hardware enhancements adapting performance of the airport environment. The FAA performed full functional and operator evaluation of this system (see *Low-Cost ASDE Evaluation Report: Raytheon Marine (Phase I) Radar at MKE (ARPA M3450 / 18CPX-19)*.

The Marine Radar evaluation was a precursor to the testing of Raytheon's ASDE currently installed in Bombay International Airport. For a $250k equipment cost, a scaled down version of the India ASDE—minus the tracker, safety logic, and system redundancy—was configured for testing at Milwaukee's General Mitchell International Airport (MKE). The MKE staff's insight and experience gained through Phase I figured prominently in the success of the installation and testing of the Raytheon ASDE. Installation costs were minimized by reusing the marine system's pedestal, waveguide, power, and signal cabling. Local MKE staffers used their experience with the airport layout and Phase I testing to develop and execute an operator's test tailored to the AT environment.

Test results show that the Raytheon ASDE has great potential as a low-cost surveillance solution. AT found that the ASDE enabled them to confirm pilots' reported positions and aircraft/vehicle compliance with instructions, and aided their clearances of aircraft/ vehicles on the movement area during low visibility operations. Controllers were able to produce a clean radar presentation and detect targets throughout the movement area. Detections were credible in snow, rain, fog and in snow covered surface conditions. The controllers identified system shortcomings related to operators functionality and to the human/machine interface. The controller's comments and the test data herein will provide the FAA with valuable input toward the development of functional specifications for runway incursion reduction systems.

OVERVIEW

This brief overview serves as the reader's roadmap to this report's sections and appendices.

Section 1 describes the radar system: each major component of Raytheon's ASDE radar system used for MKE's Phase II testing is listed with its specifications. Section 2 begins with an explanation of the MKE environment: airport profile, recent incursion history, reduced visibility data, and fog quotient. A brief summary of the site survey follows, adapted from the *Site Evaluation Report*. The installation reviews the Statement of Work, schedule, costs, plan, and actual installation, including safety considerations.

Sections 3 and 4 describe the entire sequence of tests performed by the evaluation team. Section 3 begins with equipment checklist and calibration, set-up and DGPS survey. Functional tests include measurements of the radar components (transceiver, display, waveguide, antenna), radar alignment with fixed target reflectors (FTRs), and map generation. Data sheets provide a checklist summary of all recorded calculations and checked verifications.

Evaluation of the radar (Section 4) by its users–Air Traffic Controllers–begins with explanation of the test format, background data, radar screen definitions, and the test coordinators' pretest form. Fourteen operators' tests of the ASDE effectiveness follow; each of them focuses on a specific area of system operation, such as aircraft presentation, target registration, and false target display.

Section 5 analyzes ASDE performance and makes recommendations for post-Phase II modifications. MKE ASDE performance history is reviewed, and direct comparisons are made between ASDE and ASDE-3 system profiles. Task performance is analyzed for range and azimuth resolution, height coverage, isolation and identification of false targets. Recommendations are made regarding suggested improvements for Phase II and future versions of the radar.

Appendices follow. Appendix A details the manufacturer's system alignments. Appendix B describes the METAR and RVR weather reporting code systems. Other appendices address Display Satisfaction Questionnaire (C), RSEC Calculation (D), Spares List (E), Ancillary Documents (F), (e.g., Raytheon's Certification Report, Frequency Transmission Authorization, and FAA's construction permit for FTRs.) Appendices G and H are the Glossary and Acronym List, respectively. Appendix I, a comprehensive Bibliography, lists references and other project papers, such as Maintenance Procedures.

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1. RADAR SYSTEM

As part of the Runway Incursion Reduction Program (RIRP) effort, the Federal Aviation Administration (FAA) installed and evaluated a Raytheon marine radar (ARPA M3450 / 18CPX-19) at Milwaukee's General Mitchell International Airport (MKE). The system, bought as a Commercial Off-the-Shelf (COTS) product, was evaluated from January to October, 1996 and was successful in displaying targets of various types and sizes on the airport surface under low visibility conditions.[1] The radar is considered a potential solution for surface surveillance at small airports, or as a secondary sensor to enhance higher-end ASDE-type systems.

This marine radar evaluation was regarded as a precursor (Phase I) to the testing of Raytheon's ASDE system (the current Phase II) developed for the Government of India, and currently installed at Bombay's International Airport. The RIRP team purchased and installed a scaled-down version of Raytheon's ASDE with no tracker. The elimination of the tracker required Raytheon's development team to customize utilities for building airport maps and creating masks.

Equipment costs in the MKE evaluation efforts were kept to a minimum, by eliminating system redundancy requirements (multiple transceivers, display processors, and displays) and by reusing Phase I equipment (see Section 1.3.)

The ASDE (Phase II radar) installation at MKE afforded the FAA the unique opportunity to implement operators' requests and evaluate enhancements in a short time span at the identical test site with the same personnel.

Upgrades and expected performance improvements over Phase I included:

- Reduced clutter return by narrowing antenna vertical beamwidth from 19° to 12°
- Improved visual target tracking by increasing update rate from 2.5 to 1 per second
- Increased range resolution by decreasing pulse width from 60 to 40 nsec
- Lessened controller workload with automated frequency control
- Cleaned up display presentation with added masking capability
- Improved mapping capability and clarity with more map lines.

1.1 SIGNAL AND DATA FLOW

The ASDE radar system provides for the detection of ground targets during low visibility conditions on all airport movement areas. The radar is an adaptation of the Raytheon Marine STV TS system. The X-band (9.375 GHz) pulse-type radar supplies 360° of coverage with one-second updates. The radar consists of four major components: transceiver, antenna / pedestal, display processor (DP), and user display with control suite. Other items include a slow start unit, dehydrator, waveguide, and wiring. Each component is described in Section 1.2. This section describes the signal and data flow; a system block diagram (Figure 1-1) illustrates how system components work together.

Target detection starts with the radar's transceiver. The transceiver provides the system with 40 nsec pulses at a PRF of 4096 kHz with a minimum peak power output of 25 kW. The system's major transmitter components include a control Printed Circuit Board (PCB), a modulator, a magnetron, and a circulator. The receiver end includes a TR limiter, low-noise amplifier (LNA), and an Intermediate Frequency (IF) amplifier. The process begins at the control PCB, which generates a trigger pulse, with input from the system's encoder. The trigger is routed to the modulator, which pulses the magnetron. The Radio Frequency (RF) is then routed to the antenna via the circulator. The receiver is protected during transmission by the circulator and TR limiter.

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[1] Cf. *MKE I Report,* Section 4 (see Appendix I).

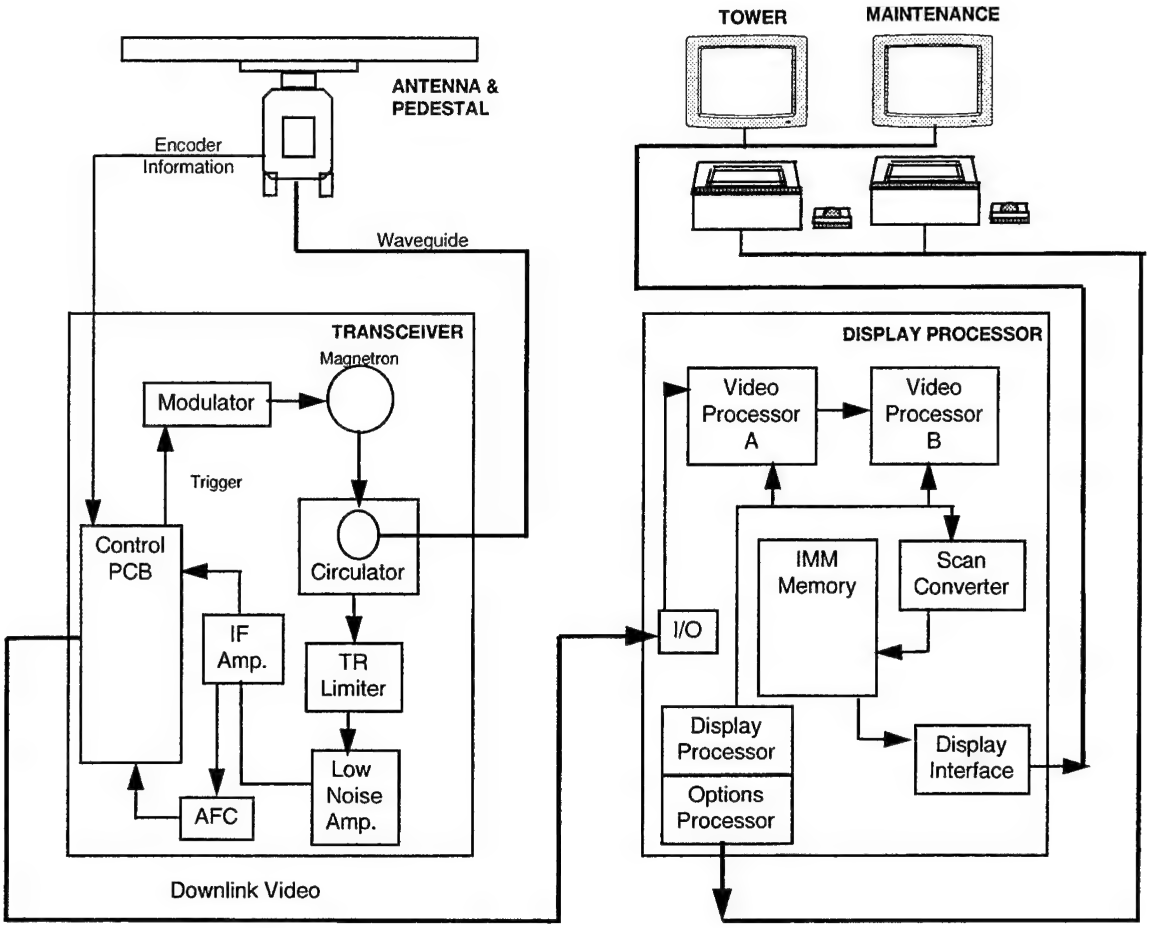


Figure 1-1. ASDE Signal and Data Flow Diagram.

The pulsed energy is transmitted via the waveguide through the 18-foot slotted antenna array. The antenna provides fixed circular polarization, a 0.45° (3 dB) point horizontal beam, and a 12° (3 dB) vertical beam. The pedestal's 3 HP motor, coupled with the antenna's minimized vertical face, allows operation in winds up to 80 kt. Signals travel from the antenna to the airport surface, hit targets in their path, and are reflected in all directions. A fraction of the scattered signal returns directly back to the antenna, and into the receiver. The returned signal travels down the waveguide to the receiver front end via the circulator, which switches return to the receiver port. The LNA mixes the RF with input from the local oscillator to create a 60 MHz IF which is routed to the display processor and the Automatic Frequency Control (AFC) via the control PCB.

The display processor is a computer controlled radar information terminal that uses raster display technology. Downlink data (trigger, video, and antenna position) from the transceiver control PCB are sent through the I/O to a pair of video processors. The first processor separates the downlink into its component parts. The radar video is subsequently processed to remove clutter, and converted to digital video. The digital video is then sent to the second processor, which performs pulse and beam processing, removing interference and noise. The output is scan-converted and distributed into IMM memory in an x,y matrix format, which is rho-theta (polar). Synthetic video, in characters and symbols, is generated on the scan converter and written to memory.

Upon command of the display interface, the stored information is read and combined to produce and send a digital video signal to the operator and maintenance displays. The display covers a square viewing area

on the left 2/3 of the monitor. The right 1/3 displays readouts of system conditions and status. The display shows all targets seen by the radar at their correct range and bearing from the control tower. Bar graphs indicate readings of individual radar controls: GAIN, Sensitivity Time Control (STC), RAIN, and Fast Time Constant (FTC). Other data–such as position in latitude and longitude--are shown along with miscellaneous functions.

The touch pad and trackball allow user interface with the system. The touch pad contains all of the selections available to the user, such as display settings, and map functions. The display functions permit viewing of different ranges and offsets, as well as changing the presentation, or aspect, of a target. Target presentations are adjustable via the four radar controls.

GAIN adjusts the overall amount of radar returns on the display. By increasing the GAIN, smaller targets appear larger, but so does undesirable clutter.

Sensitivity Time Constant (STC) is used to suppress land clutter. The STC and GAIN controls are used together to both reduce clutter returns to a light background speckle at low brightness and define targets in clutter at high brightness levels.

RAIN is used to suppress clutter caused by rain in the vicinity of the radar. Adjustments are made to minimize rain clutter returns to a light speckle. This control will have little effect on strong, moving targets.

Fast Time Constant (FTC) restores weak targets that are suppressed along with the rain clutter. FTC is used by adjusting the control until the leading edge of the rain clutter is just visible. As FTC is increased, weaker targets re-appear and stronger targets decrease in size.

1.2 ASDE COMPONENTS

Descriptions of the ASDE radar components are based on the manufacturer's product information for the ASDE system delivered to India. Basic differences between the MKE and Bombay systems are that MKE lacks a second (redundant) transceiver, a tracker, a Performance Monitor Unit, and a Switching Monitor Unit. Figures and specification tables are based on those in Raytheon's ASDE Manual (see Raytheon, Appendix I).

1.2.1 Transceiver

The Phase II transceiver (Figure 1-2; the unit is identified in Raytheon drawings as MTR, or Modulator Transmitter / Receiver) is the ASDE solid-state STX, transmitting in X-band at a frequency of 9375 ± 30 MHz, with a transmitted pulse width of 40 nsec ± 8 nsec and a receiver bandwidth of 30 MHz. The transmitter uses a 25kW magnetron, driven from a solid-state pulse modulator. The modulator uses a pulse-forming network to store and produce the drive pulse for the magnetron. Transceiver specifications are listed in Table 1-1.

The receiver's low-noise RF amplifier feeds an image rejection mixer, which gives a receiver noise figure of under 6.5 dB. An AFC circuit monitor and stabilizes the receiver's IF of 60 MHz from the transceiver, and also adjusts the tune voltage to the LNA. The receiver IF has a fixed-band pass filter (24 MHz) to match the short (40 nsec) pulse width.

1.2.2 Antenna

The antenna array (Figure 1-3) is an 18-foot, X-Band, slotted waveguide antenna with fixed, circular polarization for the horizontal beam, and flares for the vertical beam. The array has a 0.45° (3 dB) horizontal beamwidth and a 12° (3 dB) vertical beamwidth. The array's vertical face is rounded to reduce drag. Antenna specifications are listed in Table 1-2.

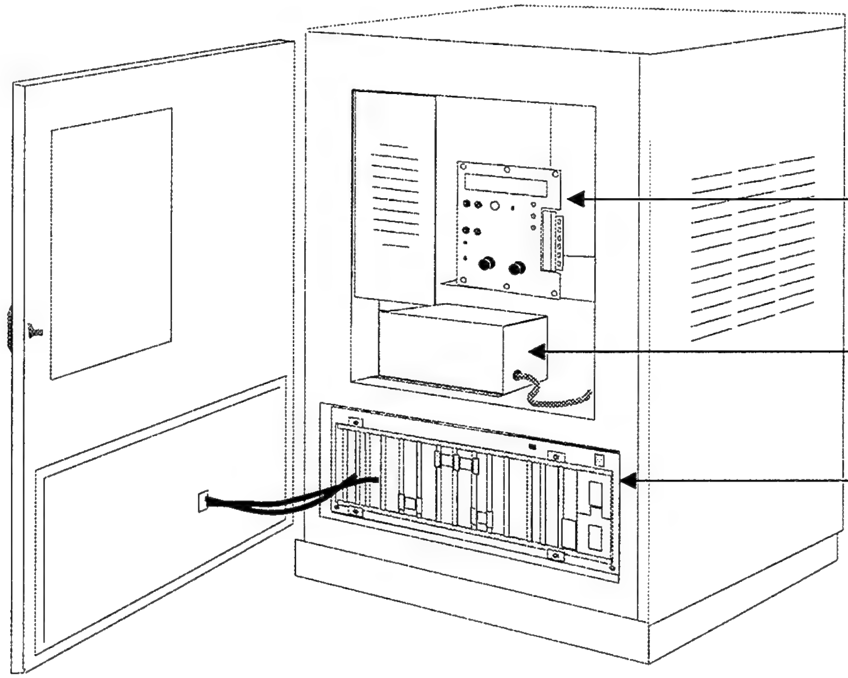


Figure 1-2. Transceiver and Equipment Rack.

Table 1-1. Transceiver Specifications.

Output Power (Peak):	> 25 kW
Frequency:	9375 ± 30 MHz
Frequency Variation, normal operation:	± 5 MHz
Output Device Type:	Magnetron
Pulse Repetition Frequency:	4096 ± 140 Hz
Pulse Width:	40 ns ± 8 ns @ 3 dB
Receiver Type:	Logarithmic
Receiver Noise Figure:	3.5 Db (Low Noise Amplifier)
Minimum Discernible Signal:	–91 dBm Maximum
Receiver Bandwidth:	40 MHz
Dynamic Range:	80 dB Minimum
IF Frequency:	60 ± 5 MHz
Video Bandwidth:	16 MHz Minimum
Environmental Requirements	
Operating Temperature:	0° to +55° C
Humidity:	0 to 95% Relative
Vibration:	1g Peak at 5 to 50Hz in 3 perpendicular planes
Shock:	5g
Cabinet Size (including DP)	51.5" high, 27" wide, 30.5" deep
Cabinet Weight (including DP)	485 lb.

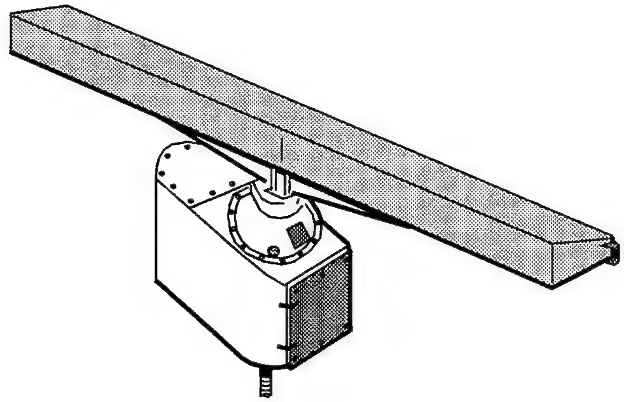


Figure 1-3. Antenna and Pedestal.

Table 1-2. Antenna Specifications.

Type:	Slotted waveguide array, flared-horn reflector
Horizontal Beamwidth, @ 3 dB Pt:	0.45° ± 0.05°
Vertical Beamwidth, @ 3 dB Pt:	12.0° Maximum
Gain:	36 dB Minimum
Polarization:	Circular
Horizontal Sidelobe Level:	> 30 dB Maximum, within ± 10°
VSWR (at rotary joint input):	1.5:1 Maximum
RF Power Input:	100 kW Peak, 100 W Average
Swing Circle:	222" (diameter) (563.99 cm)
Weight:	120 lb. (54.5 kg)

1.2.3 Pedestal and Slow Start Unit

The X-Band pedestal (see Figure 1-3) supports the antenna array and its 3 HP motor reliably rotates the array at 60 RPM. The pedestal houses the drive components (motor, reduction gearing) and the azimuth encoder which monitors and transmits antenna position information to the display. The pedestal also contains a rotary waveguide joint, which permits RF energy transmission between transceiver and antenna. Pedestal specifications are listed in Table 1-3.

The antenna slow start unit provides an adjustable antenna rotation acceleration from zero rpm to the 60 rpm normal antenna rotation speed. It also provides an adjustable current limit (a self-calibrating, energy saving feature), an adjustable overload protection, phase loss protection, and sorted silicon control rectifier detection. The slow start unit, mounted in the cable chase room, reduces motor voltage under light-load conditions; its specifications are listed in Table 1-4.

Table 1-3. Pedestal Specifications.

Height (without array):	34.5"
Height (with array):	49"
Weight (without array):	250 lb.
Weight (with array):	370 lb.
Input Power Requirements	
Input Voltage:	208 VAC, 3 Phase, 60 Hz, 1.4 A
Input Voltage Fluctuation:	± 10% [AC units, –15%, +25%, DC Units]
Frequency Variation:	± 6% [AC Units]
Phase Balance [3-Phase Units]:	5% Voltage, ± 5° Phase Angle
Drive Motor:	3 HP
Environmental Requirements	
Operating Temperature:	–25° C to + 65° C (–13° F to +149° F)
Humidity:	100% Relative
Vibration:	2g Peak @ 5 to 30 Hz
Shock:	15g (OP)
Wind:	80 knots (relative, OP), 100 knots (NOP)
Ice:	1" Build-Up (OP)
Dimensions (excluding T-Bar):	34 1/2" high, 25 5/8" deep, 14 15/16" wide
Antenna Mount:	5.63" x 40"

Table 1-4. Antenna Slow Start Unit Specifications.

Ambient Air Temperature, Storage:	– 30° C to + 70° C [– 22° F to + 158° F]
Ambient Air Temperature, Operating:	– 20° C to + 50° C [– 4° F to + 122° F]
Adjustable Voltage Acceleration Time:	0.5 to 30 seconds
Adjustable Output Current:	8 to 16 Amps, in 0.25 Amp increments
Short Circuit Withstanding Current:	5,000 Amps
Max. Thermal Magnetic Circuit Breaker Rating:	30 Amps
Nominal Input Voltage:	115/220 VAC, 60 Hz
Maximum Fuse Rating:	30 Amps
Current Derating, Up to 3,000 ft. Altitude:	None
Current Derating, Above 3,000 ft.:	2% per 1,000 ft.

1.2.4 Processor

The X-Band display processor (DP) shares the same equipment rack with the transceiver (see Figure 1-2) in the equipment cable chase room at the MKE Air Traffic Control Tower (ATCT). The DP's cardbasket contains the requisite PCBs and interconnections to process the radar video signal, generate blanking masks, and produce a raster-formatted display image. The cabinet power supply is 115 VAC / 120 VAC. DP specifications are listed in Table 1-5.

Table 1-5. Display Processor Specifications.

Beam Correlation:	2 to 8 sweeps, 50% correlation
Maps:	2, operator selectable
Map Size:	1000 points
Map Line Types:	solid and dashed
Blanking Mask:	0 to 20 nm
History Tails:	3 Levels and Off
Moving Target Enhancer:	Standard
Scan Conversion:	Custom VLSI eliminates data holes; no data overwritten
Microprocessor:	Motorola 68030 series
Program and Map Storage:	PROM and EEPROM
Sense LEDs:	Signal flow indicated by LEDs on PCB
AC Input Voltage:	110 / 220 VAC ± 15% 50/60 Hz
AC Input Power:	750 W, Maximum (entire rack)
Cooling:	Fan Cooled

1.2.5 Display Monitor, Touch Pad and Trackball

The Phase II radar display monitor (Figure 1-4) is attached to a temporary overhead swing arm to ease it up and out of the controllers' line of vision when not in use. The touch pad control unit (Figure 1-5) and trackball allow access to the operator's display functions. Specifications for monitor and touch pad are listed in Tables 1-6 and 1-7.

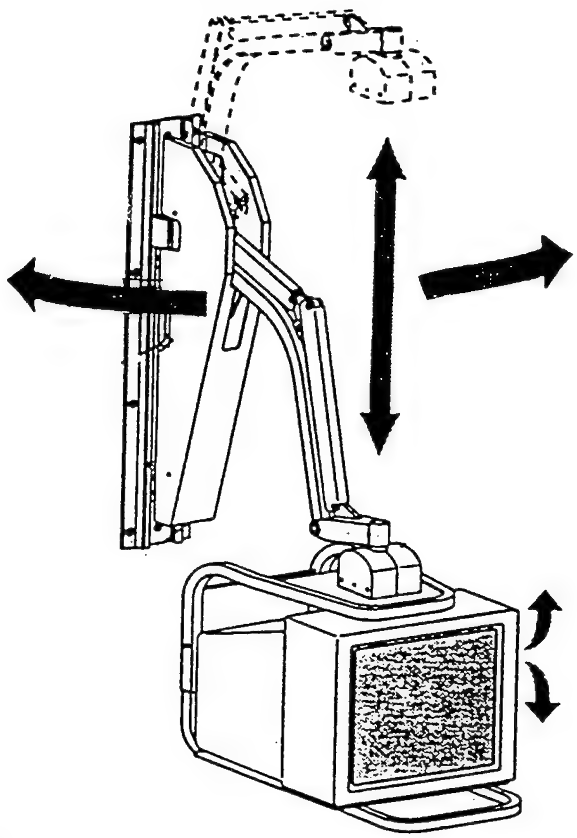


Figure 1-4. Display Monitor and Swivel Arm.

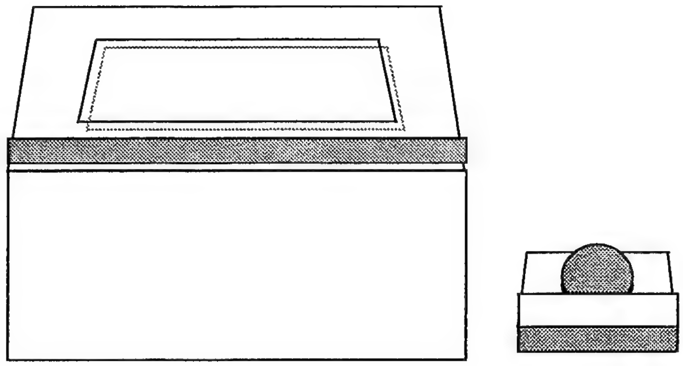


Figure 1-5. Display Touch Pad and Trackball.

Table 1-6. Monitor Specifications.

Display Screen Size (Diagonal):	58.4 cm (23 ")
PPI Diameter:	34 cm (13.4 ")
CRT Phosphor:	Green (P-39)
Resolution:	768 x 1024 non-interlaced (786,432 pixels)
Radar Display:	768 x 768 pixels (589,824 pixels)
Sample Rate:	38.8 MHz maximum
AC Input Voltage:	115 / 230 VAC, 50 / 60 Hz
AC Power Consumption:	175 W nominal
Minimum Range:	25 meters (27 yards)
Range Resolution:	0.3% or 3.6 meters, whichever is greater.
Bearing Accuracy:	1°
Bearing Resolution:	0.3°
Size:	18.9 " high, 20.4 " wide, 24.7 " deep
Weight:	80 lb.
Power Consumption:	115 VAC, 2.6 A

Table 1-7. Touch Pad Specifications.

Technology:	Backlit Transflective LCD
Matrix:	640 x 400 pixels
Power:	90 - 265 VAC
Frequency:	40-44 Hz
Viewing & Touch Area:	4.84" (h) x 7.68" (w)
Touch Technology:	Infra-red
Environmental Requirements	
Operating Temperature:	0 - 50° C
Storage Temperature:	20 - 60° C
Humidity:	0 to 100%

1.2.6 Dehydrator

The dehydrator (Figure 1-6) is a MR-050 Series commercial unit manufactured by Andrew. The positive low-pressure (~ 4 lb. PSI) dry air it supplies to the EW-85 waveguide assembly prevents the moisture accumulation with temperature changes that could lead to arcing. Dehydrator specifications are listed in Table 1-8.

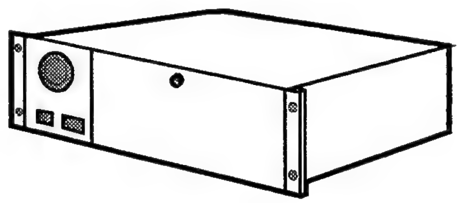


Figure 1-6. Dehydrator.

Table 1-8. Dehydrator Specifications.

Pressure Range:	3.0 to 5 ± 0.3 lb. PSI
Output Flow Rate:	3 cubic feet per hour
Output Temperature and Dew Point:	32° to 100°F, –40°F
Input Power Requirements:	115 VAC, 60 Hz
Low Pressure Alarm Set Point:	0.5 lb. PSI
Desiccant Material:	Color indicating material, w/drying capacity approx. 200 cu ft at 80% relative humidity.
Power Input:	120 VAC, 60 Hz, 170 W
Size:	6" high, 8.6" deep, 19" wide
Output Connector:	Single 3/8" compression fitting, w/shutoff valve

1.3 SYSTEM COST

The cost of the ASDE system was $247,949. Equipment re-used in Phase II helped defray costs: pedestal, waveguide, power and signal cabling. One-time engineering fees included system adaptation for non-redundancy, and the developement of map and mask utilities. Line-item costs were as follows:

ASDE Transceiver/Processor Cabinet	$75,571
Hi-Brite Display, Control Panel, Trackball, J-box	37,332
60 RPM Modification to existing pedestal	1,144
External Antenna Controller	893
Antenna Array (18 CPX-12)	54,764
Non-recurring Engineering Fees	71,249
Training Costs	6,996
Total Cost	$247,949

2. INSTALLATION

This section details the installation of the Phase II (Raytheon M3625 / 18CPX-12) radar in the MKE ATCT. The evaluation team surveyed the MKE site initially in July 1995 and prepared the *Site Evaluation Report.*[1] The Phase I removal (10/20 to 11/8/96) and Phase II installation (10/29 to 11/25/96) operations were scheduled to avoid significant impact on normal airport operations.

An MKE airport profile (Section 2.1) discusses the airport's selection for this radar evaluation effort, citing updated weather and incursion data. The Statement of Work (Section 2.2) reviews the FAA delivery order to procure installation support for MKE's Phase II; TAMSCO was awarded the contract. Section 2.3 summarizes briefly TAMSCO's *Installation Plan* and *Installation Report.* System alignments and adjustments are detailed in Appendix A; installation certification documents (e.g., Raytheon's system certification, FAA frequency transmission authorization and FTR siting permit) are displayed in Appendix F.

2.1 AIRPORT PROFILE

Milwaukee's General Mitchell International Airport (MKE), located in Cudahy, WI in the Great Lakes Region (AGL), was designated as the ASDE test site for three salient reasons: a recent incursion (see Section 2.1.1) which caused local AT to request an ASDE surveillance system, the persistent lakeside fog conditions (see Section 2.1.2), and the airport's fast growth rate. According to FAA projections, MKE, a Level 4 facility, will be the eighth fastest growing airport in the United States over the next decade.

The MKE airport map (Figure 2-1) shows five working runways: 1L - 19R, 1R - 19L, 7L - 25R, 7R -25L, 13 -31. During the summer of 1996, between the two radar test phases, reconstruction of Rwy 7L / 25R moved its east axis from 240° to 253° and lengthened it from 3163' to 4100'. Existing runway configurations for ILS approach are: 1L (Cat III), 19R (Cat I), 7R (Cat I). Other relevant airport data is shown in Table 2-1.

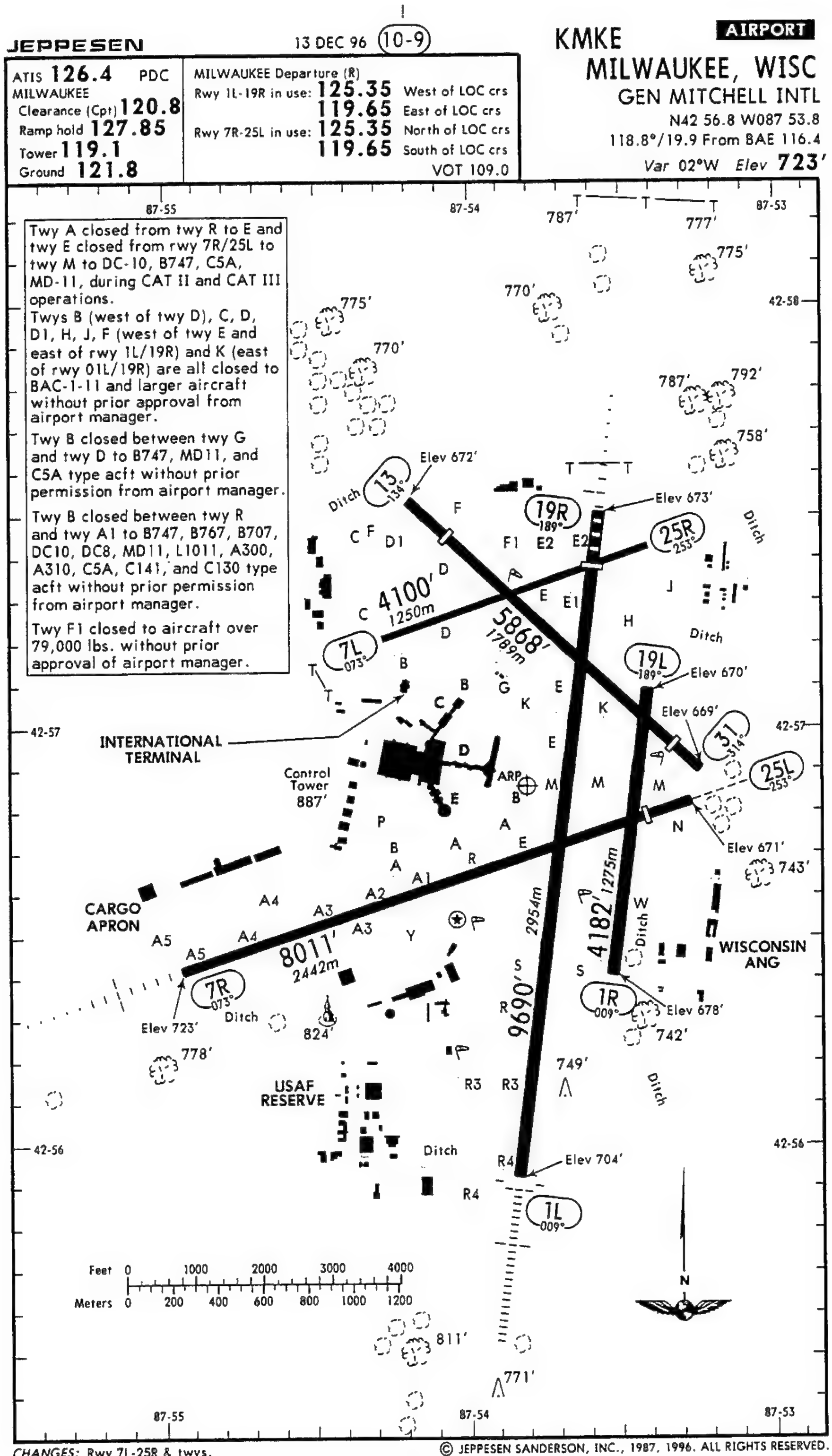
Table 2-1. MKE Airport Data.

Airport Elevation	723.5 MSL
ATCT Height	204.5 ft.
Maximum range to Runway Ends	1.5 nm
Mean max. temp. of hottest month (8/96)	81.4 ° F
Airport Navaids	ASR, NDB, LLWAS, ILS, RVR
Airport Reference point	Lat. N 42° 56' 48.432" Lon. W 87° 53' 49.224"
Airport Category	Transport
Airport Reference Code	MKE

2.1.1 Incursion Data and History

MKE incursion data is shown in Table 2-2. MKE experienced eight runway incursions during 1993-96: one in 1993 (out of 201,000 airport operations), three in 1994 (216,000) three in 1995 (192,000), and one in 1996 (201,000). The MKE incursion rate shows a steady increase over the last five years but one: 1992 (0.493), 1993 (0.497), 1994 (1.390), 1995 (1.566), then a sharp reduction in 1996 (0.498). (In each of these years, MKE's average incursion rate has been higher than the national average incursion rates[2] which, from 1992-6, were 0.35, 0.30, 0.33, 0.40, and 0.47, respectively.)

1 *MKE I Report,* Vol. II, Ap. B (see Appendix I).
2 FAA AASI, p. 2-40 (see Appendix I).



(Reprinted with permission of Jeppesen-Sanderson, Inc.)

Figure 2-1. MKE Airport Map (Jeppesen).

Table 2-2. MKE Incursion Data.

Year	*Total Incursions*	*Pilot Deviation*	*Operator Error*	*Airport Ops (k)*	*MKE Rate*	*Nat'l Avg.*
1992	1	0	1	203	0.493	0.35
1993	1	1	0	201	0.497	0.30
1994	3	1	2	216	1.390	0.33
1995	3	1	2	192	1.566	0.40
1996[3]	1	1	0	201	0.498	0.47

Four of MKE's nine incursions during this period were pilot deviations and five were operator errors, with no vehicle/pedestrian deviations. Of the two weather-related incursions, one was a pilot deviation and one an operator error. Since the ASDE radars seek to reduce weather-related incursions, those two events are summarized below.[4]

Pilot Deviation

The MKE weather-related pilot deviation took place on April 26, 1995 at night (Universal Time Code (UTC) 2223). It involved a wrong turn made by a DC9 in fog where the MKE local controller (LC) could not see the aircraft, whereas the pilot of a holding aircraft (AC2) could. Refer to MKE Airport Map, Figure 2-1[5]. The following summary of the incident is adapted from the FAA's Investigation of Pilot Deviation, Report PGLT-MKE-95003.

> *The DC9 landed on Rwy 7R. A second aircraft (AC2) was in position and hold on Rwy 19R. LC asked DC9 its position, and pilot responded by intersection of 19R. LC instructed DC9 to turn left on Rwy 19L and stay with him. DC9 responded roger. When LC asked DC9 if he was clear of the intersection, he responded yes. LC cleared AC2 for takeoff Rwy 19R. AC2 declined clearance, saying that he could see lights ahead on 19R. LC asked DC9 if he was on Rwy 19R, and he responded yes. Note that LC could see neither aircraft nor the runways in the fog, but since the aircraft could see each other, a more serious occurrence was prevented.*

Operational Error

The MKE weather-related operational error occurred on January 25, 1994 at UTC 1525. In this case, according to the FAA's Operational Error / Deviation Report MKE-T-94-E-001, an air traffic controller did not fully brief the relieving specialist of the specific presence and location of [a county vehicle] on Rwy 19R."

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3 FAA ASSH, p. 5-9, shows actual activity thru 10/31/96; the Office of System Safety provided as yet unpublished activity data between 11/1/96 and 12/31/96.

4 Adapted from *MKE I Report,* p. 2-2.

5 The MKE Airport Map, updated by Jeppesen, Inc. in 12/96, now shows (among other upgrades) the recent paralleling of Rwy 7L / 25R to Rwy 7R / 25L.

2.1.2 Reduced Visibility Data

MKE's proximity to Lake Michigan subjects it to occurrences of fog, snow, rain, freezing rain, and mist. These low visibility conditions severely hamper ATC operations. MKE's short-term low visibility data summary[6] (Table 2-3)-based on surface observations taken at 3-hour intervals for the year (a typical one) immediately preceding Phase II installation-records at least one fog observation every two days (56.7%).

Table 2-3. MKE Low Visibility Data Summary.

Month/Year	Days with Fog Observation[7]	Number of Observations[8] w/ Visibility		
		1–3 miles	.5–1 mile	≤ .5 mile
September '95	11	4	0	1
August '95	25	23	5	4
July '95	15	10	1	6
June '95	19	13	1	1
May '95	13	8	1	4
April '95	16	15	11	3
March '95	14	12	15	4
February '95	12	9	1	0
January '95	17	25	11	9
December '94	25	33	7	6
November '94	13	10	8	2
October '94	13	7	1	2
September '94	24	16	5	2
Total	**217**	**185**	**67**	**44**

MKE's meteorological history, corroborating the one-year record, has amassed a significant percentage of 1-hour fog observations between 1961 and 1990 (Table 2-4). The airport's occurrences of low horizontal visibility show a 30-year average of 12.1% for visibility up to ½ mile and 11.4% for visibility ½ to 1 mile, or 23.5% in the range most seriously affecting tower observations of surface acvtivity. The annual MKE average 1-hour observation rate of all occurrences is 1262 (14.7%), of all snow occurrences, 2131.

Table 2-4. MKE 30-Year Fog Occurrences[9].

Distance	***≥ ½ mi.***	***1 mi.***	***2 mi.***	***3 mi.***	***4 mi.***	***5 mi.***	***6+ mi***	***Total***
Lo-Vis Observations	3678	3467	6106	5714	4946	3669	2724	30304
% L-V Obs Total	12.1	11.4	20.1	18.9	16.3	12.1	9.0	100%
% L-V Obs Cumulative	12.1	23.5	43.6	62.5	78.9	91.0	100	100%
% All Obs Total	1.75	1.65	2.90	2.72	2.35	1.74	1.29	14.4%
% All Obs Cumulative	1.75	3.4	6.3	9.0	11.4	13.1	14.4	14.4%

6 NOAA data from archives supplied by the National Climatic Data Center, Asheville, NC.
7 Total days for the given month with at least one 3-hour observation fog.
8 Each visibility observation is counted as a separate occurrence; visibility 4-6 mi. omitted.
9 Data, supplied via Samson (Solar and Meteorological Surface Observation network, is based on 210360 total 1-hour observations over 30 years.

2.2 STATEMENT OF WORK

The statement of work for Phase II took the form of Modification 003 submitted by TAMSCO of Calverton, MD, awardee of the original Phase I contract–Contract No. DTRS-57-93-D-00145, Delivery Order 002. The objective of the FAA's modification was to procure support in the installation of the Raytheon ASDE radar at MKE. The task, including developing the installation plan and other documentation, was broken down into the following location-oriented modification items to the Phase I effort:

1. **Antenna Installation** included ATCT rooftop modifications: removal of the old antenna array, installation of the new antenna, replacement of the pedestal drive motor, adaptation of the waveguide feedthrough.

2. **Tower Cab Installation** included replacement of integrated display, processor, and control panel unit with hi-brite monitor, touch pad, and trackball; removal of cable drop and ceiling suspension of monitor; console mounting of touch pad and trackball.

3. **Cable Chase Room Modifications** included replacement of the transceiver, installed in a rack with the processor cardbasket; installation of the antenna slow-start unit; upgrades of the existing Power Distribution Panel (PDP.)

4. **Wiring Upgrades** included replacement of wiring from the transceiver to the tower cab and installation of a J-box to support the operator's suite.

2.3 RADAR INSTALLATION [10]

The Phase I radar, installed at MKE in October 1995, was the Raytheon ARPA M3450 / 18CPX-19, from the AN/SPS-64 family of marine radars. Phase I component installations were as follows: transceiver in the cable chase equipment room; the display processor and display in the tower cab area; and the pedestal and antenna on the tower penthouse roof.

Phase I components were removed between October 20-31. The "old" antenna array was lowered and the "new" antenna raised by helicopter lift on November 8. System optimization and functional testing were held from January 6-17, 1997; operator evaluation (mapping and tests) ran between January 23-31.

The Phase I upgrade to Phase II–Raytheon's ASDE M3625 / 18CPX-12–contains ASDE-specific modifications to enhance the capability of the basic marine radar to serve as a sensor for airport surface surveillance. The differences between Phase I and Phase II configurations are summarized below. The general component configuration in the tower is shown in Figure 2-2.

2.3.1 Antenna Array

The existing (Phase I) array was replaced with an array of the same length and horizontal beamwidth (0.45° at the 3 dB point). The new (Phase II) array's vertical aperture increased to 7.06 inches, which decreased the 3 dB vertical beamwidth from 19° to 12°, thus improving resolution. The increased aperture also provides a minimum gain of 36 dB, 2 dB greater than Phase I. The weight of the Phase II array was 120 pounds, 10 more than Phase I. The mounting configuration remained the same.

10 Material for this section has been adapted from TAMSCO Tech (see Appendix I).

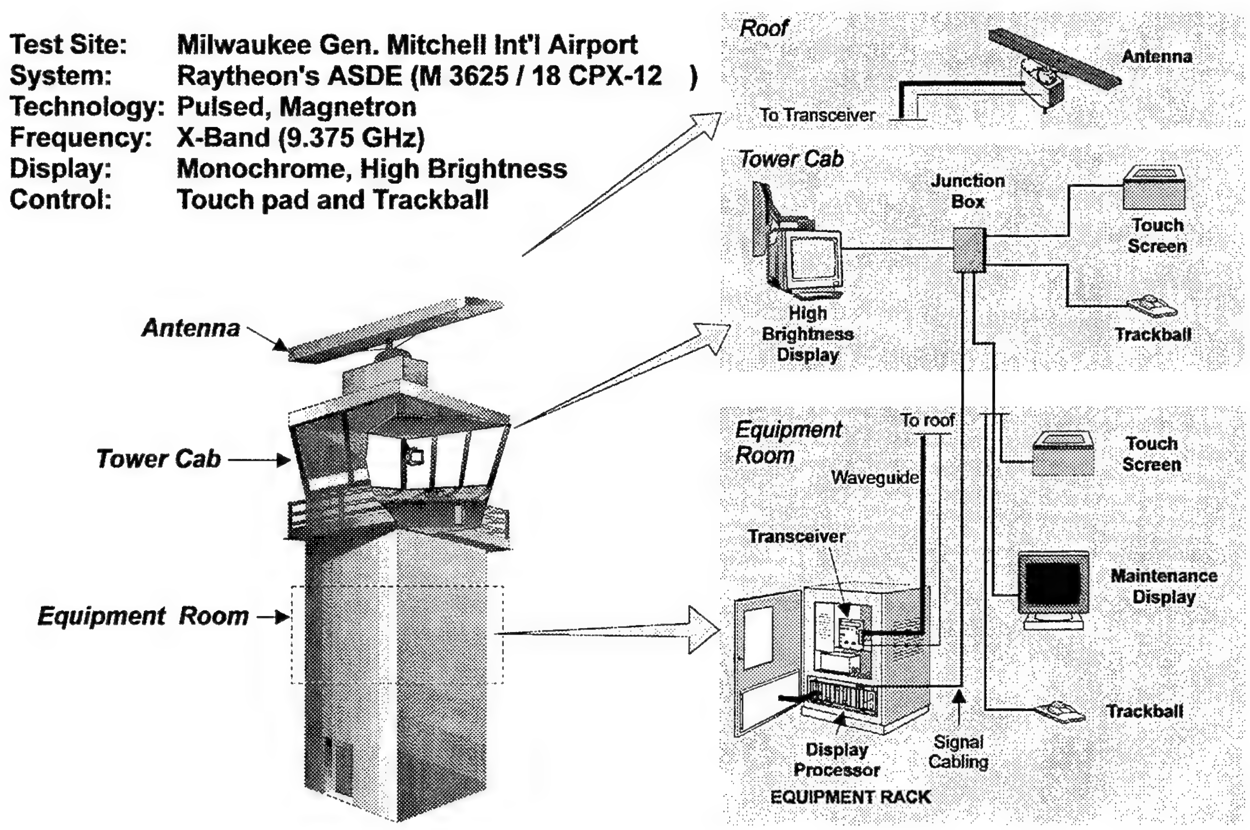

Figure 2-2. MKE ASDE ATCT Equipment Layout.

Raising an 18' antenna assembly to the top of MKE's 204.5-foot tower presented a challenge, with no adequate access via the tower's stairway entrances. There were three options: crane, hoist, or helicopter. The crane, preferred as the method the least disruptive to tower activities, proved prohibitive for both cost and logistics. A portable hoist or block and tackle, an approach both technically feasible and inexpensive, entailed the highest degree of risk to personnel and equipment. Ideal Helicopter (the Milwaukee-area outfit which raised the Phase I pedestal and array to the tower roof with minimum logistics problems and easy scheduling) was contracted to lower the old array and raise the new one. The replacement was made swiftly and without incident (see Figure 2-3.) Figure 2-4 shows the antenna in position.

2.3.2 Pedestal and Slow Start Unit

The pedestal housing remained the same. The 1 HP motor was replaced with a 3 HP unit (with drive pulleys and belt) to accommodate the added wind load resistance caused by the array's increased rotation rate (60 RPM) and surface area. The Phase II antenna drive system uses slow start circuitry to minimize the starting shock on drive components; this was mounted on the wall in the spot vacated by the Phase I transceiver. Phase II antenna positioning is determined by a shaft encoder (replacing Phase I's resolver) which synchronizes sweep with antenna rotation.

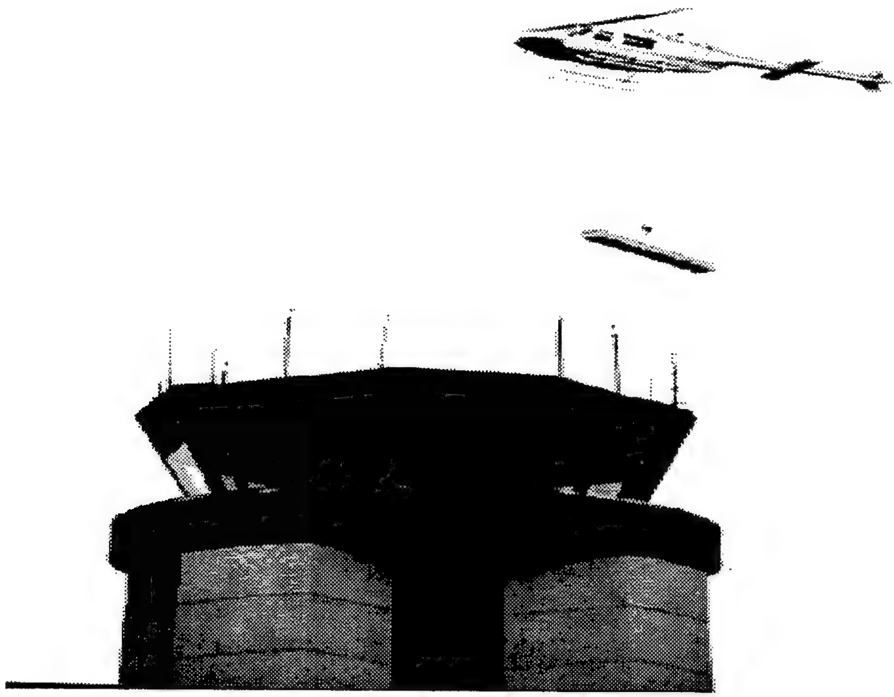

Figure 2-3. Helicopter Lift of Antenna and Pedestal.

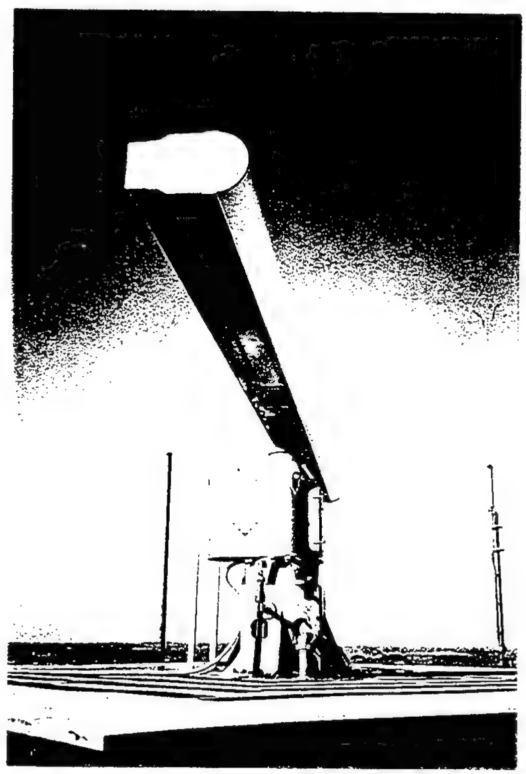

Figure 2-4. Antenna in Position on MKE Tower.

2.3.3 Transceiver

The Phase I transceiver was removed from the southwest wall of the junction level cable chase room, packaged, and shipped to the Volpe Center. The new transceiver was mounted on a rack in the cable chase equipment room (see Figure 2-5) and bolted to the floor. The Phase II transceiver has a peak power output of 25 kW, a 40 nsec RF pulse width, a pulse repetition frequency (PRF) of 4,096 pulses per second (PPS), 90 dB dynamic range, and a 4.5 dB NF front end. Other design improvements include AFC and a redesigned modulator. AFC locks the receiver's local oscillator frequency to the transmitter magnetron frequency, thereby eliminating the need for frequent retuning. The modulator redesign eliminates silicon controlled rectifiers and moves the "tailbiter" circuit to the primary (i.e., low voltage) side of the output transformer, thereby enhancing performance and reliability.

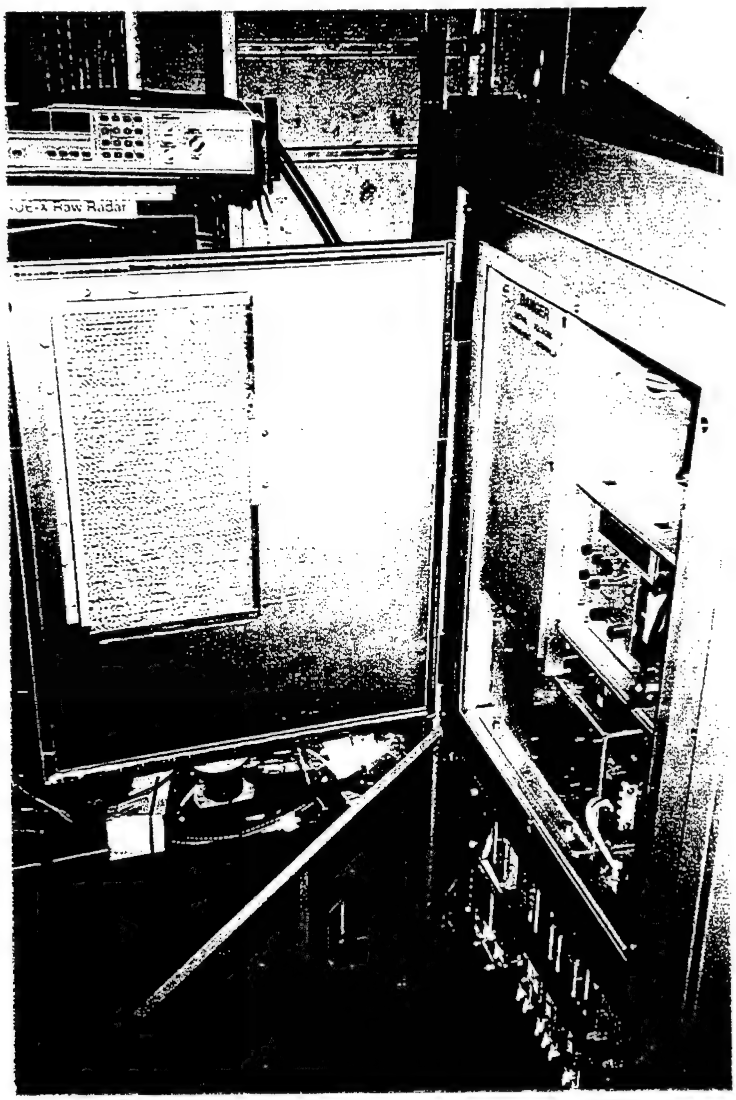

Figure 2-5. Transceiver Rack.

2.3.3 Signal Processor, Display and Controls

The Phase I display/processor console was replaced in Phase II with modular units for processor, display, and control panel. The Phase II processor utilizes ASDE-specific software, similar to the system Raytheon delivered to Bombay (India) International Airport in 1995, but excludes the latter's tracking feature.[11] The processor was upgraded to use Motorola 68030 devices to produce higher resolution (1000 point) maps. Operators can select and generate two maps and use a video blanking mask. They also may select from six range scales, in nautical miles, (1/4, 1/2, 3/4, 1, 1 1/4, 1 1/2). The display presentation was modernized from a conventional round screen to a square format, and operators can offset the origin to any point on the display. The processor is colocated with the transceiver in an equipment rack in the cable chase room.

The display, a 19" high-brightness monitor, is suspended in the tower cab from the support column east of the mullion where the waveguide run is located (see Figures 2-6a, and 2-6b.) The control assembly consists of a separate Liquid Crystal Display (LCD) touch pad and trackball. The monitor and touch control panel were adapted for the temporary installation. The touch control panel, larger than the shelf in front of the console turret, required installing a fixture to elevate the touch pad slightly to obtain sufficient depth to install controls without extending into the operator space in front of the console. This fixture was installed in the eastern corner of the cab, in front of the seldom-used VHF / UHF control panel.

2.3.4 Power, Wiring and Waveguide

As in Phase I, prime power is obtained from the power distribution panel mounted on the northeast wall of the cable chase room. A 60 amp, 208/120 volt, service is provided to the panel already in place on the southwest wall, which contains circuit breakers for each major component in the system. Single 15 amp, 115 V, 2-pole breakers are provided (one each) for the transceiver, dehydrator, pedestal convenience outlet, and display processor. One 10 amp, 208 V, 3-pole breaker is provided for the pedestal power. The control panel and monitor obtain 115 V, 60 Hz power from outlets in the base of the cab console.

Wiring was routed from the power panel up to the overhead cable chase and then down to the rack. The facility critical power source of radar prime power is a well-filtered, transient-protected, power source needing no added line conditioning components. Convenience outlets are also provided in the transceiver and adjacent to the power panel for test equipment during alignment and troubleshooting. The system interconnect diagram (see Figure 3-1, p. 3-4) includes updated cable assembly and routing information obtained from Raytheon ASDE system manuals.

The Phase I waveguide run and the portion of the wire harness linking transceiver and pedestal were re-used in Phase II. New wires were routed from the equipment rack to a J-Box mounted in the tower cab console, and short cables routed from the J-Box to the control panel and monitor. The wiring harness, secured along its entire route to provide support and protection, required installation of standoffs/clamps where the harness is not carried through an existing cable chase. Despite slight reroutings, waveguide length remained within the stipulated 50 meter maximum.

Cable and waveguide supports installed in the penthouse area were clamped to existing structure to minimize the need for drilling. The EW-85 elliptical waveguide is terminated at both ends in WR-90 waveguide for easy connection to the transceiver and antenna pedestal. The termination in the cable chase room was moved along the cable tray at the top of the room, dropped to the top of the equipment

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[11] Certain readout and graphic features of the tracker, though not functional in the ASDE system, still appear on the screen. Future software modifications may either utilize these features or remove them from the display.

Figure 2-6a. Display Mounted in Tower Window (Raised, Not In Use).

Figure 2-6b. Display Mounted in Tower Window (Lowered, In Use).

rack, adapted to WR-90, and terminated to the transceiver. The Andrew fitting in the penthouse roof was replaced with a conventional WR-90 feedthrough; this provides greater resistance to roof leaks, as well as a convenient means of sealing the waveguide should the pedestal termination need removal for maintenance.[12]

2.3.6 Harness Assembly

The Phase I harness assembly required little modification to accommodate the Phase II wiring. Phase I was routed up the southwest wall of the cable chase room and across to the cable chase located near the ceiling of the room. From that point, it was routed up to the cab level into the bottom of the console. It then exited through the back of the console on the northeast side of the cab. Both the harness and waveguide were encased in a plastic, surface-type conduit and routed along the center mullion of the northeast window, through the acoustical drop ceiling, and into the penthouse area above the cab. Phase II utilizes the original harness assembly between the transceiver and the pedestal. The portion of the harness that ran from the transceiver to the processor display unit was replaced. The new harness runs from the equipment rack in the cable chase room into the base of the cab console, where it terminates to a J-Box mounted under the console near the display/control panel. The cables from the J-Box to the control panel and the display were required to be less than 10 feet long. Routing of the harness from the rack to the cab console used existing cable trays.

2.3.7 Safety Impact on Operations and Facility

As the radar was installed as a temporary testbed, every effort was made to avoid impacting MKE operations. For the helicopter lift, concerns for safety dictated that the tower facility be evacuated; airport operations were relocated during that brief hiatus to the Midwest Express terminal.

The installation of the new monitor along the Northeast side of the cab, the focal point of controller activity, proved of minimal interference with normal operations, and required no transfer to the backup facility. No excessive noise or prolonged interference or blocked visibility was reported or observed. The two technicians required to install the cab equipment took pains to minimize any noise and obstruction, and instantly stopped work at any request of the controller on duty. The lead project engineer coordinated all installation activity with all designated site personnel.

Efforts were also made to preserve the existing tower structure and interior. Unavoidable facility modifications (e.g., installations of display and antenna, routing of waveguide/harness), were coordinated with on-site personnel and post-testing restoration was considered. Safety grounds carried throughout the harness wiring were grounded to each chassis as required. Direct current bonds were connected between the radar units, the facility power ground, and the lightning rod ground cable on the tower roof. Whenever dissimilar metals were joined, neoprene gaskets and/or anti-oxidation compounds were used to minimize the potential for galvanic corrosion.

2.4 ALIGNMENTS

The radar alignment procedures were performed after system installation was completed, and before functional testing began. These alignments ensured that the system was operating at peak performance. Alignments were performed in the order given below, starting with the transceiver, progressing to the slow start unit and display processor, and finally the full system.

Transceiver alignments (Section A.1) are a series of adjustments to the high voltage power supply, the AFC, the STC, video and data levels, and end with a minimum discernible signal (MDS) test.

The slow start unit alignments (Section A.2) involve solid state overload, current limit, acceleration ramp time, and phase loss adjustments.

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12 If the waveguide should be removed, the bulkhead feedthrough can be sealed with a standard WR-90 blank cover to provide weather-tight integrity.

Section A.3 contains display processor alignments to the +5, ±12 power supply, switch panel logic, interswitch, and adjustments to the noise threshold and FTC zero.

Finally, full system alignments entail aligning the radar to a trihedral fixed target reflector (FTR) with known position on the MKE surface. These alignments, found in the radar registration section (Section 3.7.3), are the antenna offset and zero range tests. The final alignment for the system permits the critical creation of accurate display maps, following instructions in Map Generation (Section 3.8).

2.5 PROJECT LIFECYCLE

The installation and testing of the ASDE radar at MKE followed and briefly overlapped that of the Marine system. The accompanying project lifecycle highlights salient dates, milestones, failures, and accomplishments.

11-6-95	Raytheon certifies Marine (Phase I) radar at MKE.
11-28-95	Raytheon was awarded a contract for long-lead items on the "Bombay" radar system (Phase II): to purchase the antenna array, develop the map-making and masking utilities, and modify the display. Modifications required the elimination of tracking and redundant components, and allowing the system to operate without the Performance Monitoring Unit.
12-16-95	Phase I formal operator evaluation completed.
10-20-96	Delivery of *Phase II Installation Plan.*
10-21-96	System delivery to MKE. Phase I removal and Phase II installation begin.
10-27-96	Helicopter lift to remove Phase I array and lift Phase II array to tower roof.
12-2-96	Physical installation completed.
12-5-96	Initial Raytheon attempt at certification and operator training (see Appendix F). System malfunctions and improper alignment impede certification and prevent effective training session.
1-9-97	Raytheon fixes system by improving touch pad and implementing new alignment procedures.
1-17-97	Functional testing, map and mask building completed.
1-26-97	Partial modulator failure causes maps to lose alignment to radar video.
1-27-97	Operators' evaluation begins.
1-29-97	Full modulator failure. Spare parts installed and system repaired and realigned.
1-31-97	Formal operator evaluation completed.
2-16-97	Full modulator failure; repaired in two days.
3-18-97	Raytheon firmware update resolves various display problems (map blinking, cursor offset, map protection, etc.) and inverses video color on touch pad.
3-28-97	Second functional evaluation, map registration, and mask building completed.

4-17-97	Raytheon provides modulator failure analysis.
5-7-97	System maintenance check.
5-16-97	Meeting between Volpe and Raytheon to resolve system shortcomings.
5-20-97	System maintenance check.
6-12-97	System maintenance check.
6-20-97	Raytheon completes maintenance training with local MKE radar technicians.
7-9-97	Last low visibility data recorded for use in this report.

3. FUNCTIONAL EVALUATION

This section outlines the functional test and system evaluation of Raytheon's ASDE radar system, installed at MKE. The tests aid the evaluation of the Raytheon ASDE system by providing the information necessary to verify Raytheon's performance specifications; component measurements and performance parameters are compared to those of ASDE-3 in Section 5.

Section 3.1 lists the equipment needed to perform system tests, and to calibrate each equipment element. Once the equipment is gathered and checked out, the system is calibrated to known coordinates using FTRs (Section 3.3). Functional tests performed on the system include radar transmission and reception, system measurements, display map generation, and range and azimuth resolution.

All system measurements have been tabulated in data sheets (see Section 3.11). Procedures which required the test technicians to **CHECK** compliance, to **RECORD** data, or to take **VIDEO** clips of equipment setups, are referenced on the appropriate data sheet. Safety issues have been observed, such as the disconnection of high-power components during tests.

3.1 EQUIPMENT CHECKLIST AND TESTS

General electrical engineering test equipment required included a signal generator, power meter, oscilloscope, and spectrum analyzer. Also needed were screwdrivers, Allen wrenches, and various X-band waveguide components. The complete list is given in Table 3-1. Prior to making system measurements, it was necessary to check the system installation, which depends on correct radar equipment setups and the required linking and adjustments detailed in Appendix A. Finally, system compliance with the Interconnect Diagram (Figure 3-1) was checked before the tests specified herein were conducted.

3.1.1 Radar Components

The major units of the Raytheon ASDE to be tested are described briefly below by their function:

Transceiver: Generates signal to be transmitted via the antenna, also accepts received signal.

Antenna: Device through which the transmitted signal is sent, and the received signal received.

Pedestal: Rotates antenna through 360 degrees, at 60 revolutions per minute.

Processor: Filters and digitizes data for presentation on the display.

Display: Formats and displays radar return information on hi-brite screen.

3.1.2 Test Equipment

Table 3-1 lists each unit of equipment (or its functionally equivalent model) required to perform tests on the radar. Compliance was checked for each equipment item in Table 3-2 that requires current calibration, and for all attenuators and cables in Table 3-3 (refer to Section 3.11, respectively). The attenuation and cable calibration procedure is given in Section 3.1.3.

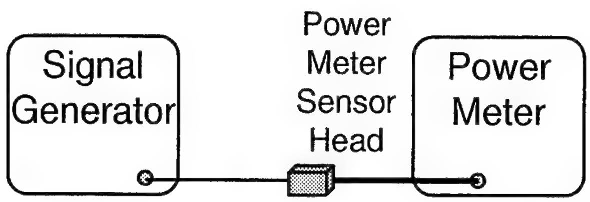
Table 3-1. Functional Test Equipment List.

Item	*Qty*	*Manuf'r / Supplier*	*Model / Part*
Electronic hand tools		Any	
9/64 Allen Wrench	1	Any	
Trimpot Adjustment Tool	2	Raytheon	
Digital Voltmeter (DVM)	1	Fluke	23(80I-600A)
Ammeter Attachment	1	Fluke	
Frequency Counter	1	EIP	585
Noise Meter	1	B & K	2236 D
Oscilloscope (Scope)	1	Tektronix	2246
x10 probe	2		
Power Meter	1	Hewlett Packard	8990A
Sensor Head	1		
Pulse Generator	1	Wavetek	801
RF Signal Generator	1	Hewlett Packard	8084D
Spectrum Analyzer	1	Hewlett Packard	8563A
Power Generator	1	Any	
High Gain Horn Antenna	1	ATM	90-442-SPEC/N
PC w/ IEEE 488 Card	1	Any	
Software		Volpe	
GPS Receiver	1	Garmin	GPS 45
Radiobeacon Receiver	1	Garmin	GBR 21
Power Supply	1	Any	12 Volt (DC)
Antenna	1	Any 4' whip	
Attenuators		Macom	3082-6191-03
50-ohm Termination	1	Any	
Detector Diode	1	Hewlett Packard	2123B
Dummy Load	1	Raytheon	1035435-1
Cables (low loss)	2	Macom	1999-0072
Waveguide Transition	1	Maury Microwave	213D2
Video Camera	1	Any (Sony)	
Fixed Target Reflectors (FTR)	2	Raytheon	1m^2 Trihedral
Fixed Target Reflectors (FTR)	2	Raytheon	3m^2 Trihedral

3.1.3 Attenuator and Cable Calibration

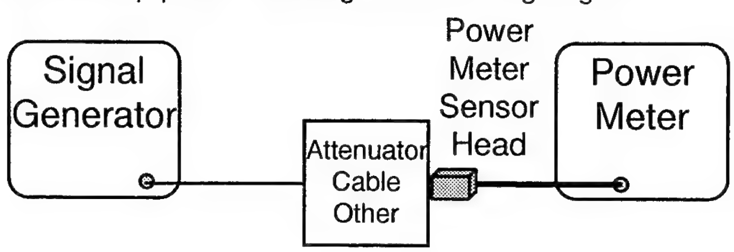
All components used in conjunction with the test equipment, including attenuators and cables, were calibrated at the test site. Calibration allows the test engineer to accurately account for power loss in each piece of equipment. Since precise values were required in the calculations, each component was measured at the site. Following is the procedure; see Table 3-3 (refer to Section 3.11).

1. Set equipment up following diagram below.



2. Adjust the signal generator so that the power meter reads 10 dBm.

3. Reset the equipment according to the following diagram.



4. Note the value of the power meter.

5. Subtract the previously noted value from 10; **RECORD**. [Table 3-2, refer to Section 3.11.]

6. Repeat the above steps for each item used during testing.

3.1.4 System

Accurate measurement of system performance cannot be conducted until the system has been installed and adjusted properly. Compliance was checked and marked in Table 3-3 (refer to Section 3.11).

1. Wiring has been done correctly. **CHECK** [See interconnect diagram, Figure 3-1]

2. System has been linked properly. **CHECK** [See linking, Raytheon document]

3. All system adjustments performed. **CHECK** [See adjustments, Appendix A].

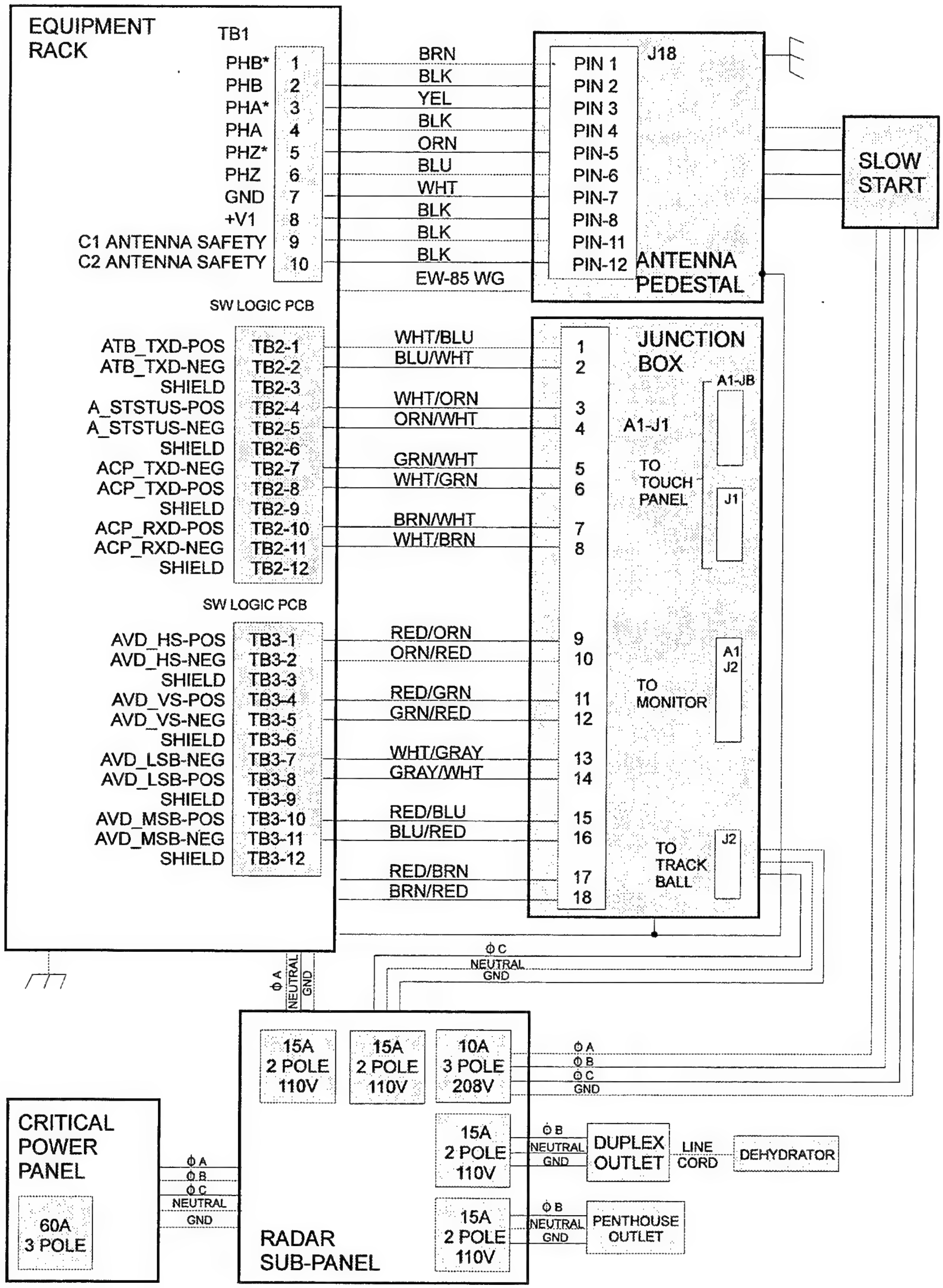
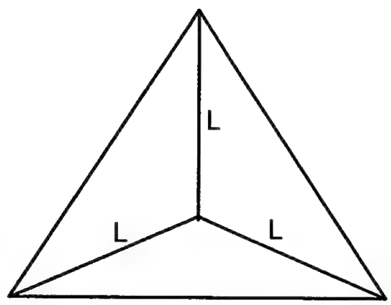


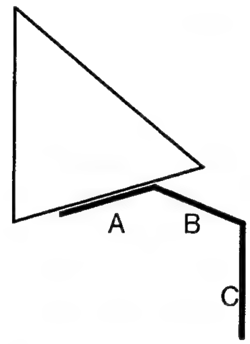
Figure 3-1. Interconnect Diagram.

3.2 FIXED TARGET REFLECTOR (FTR) SETUP

1. Check that the correct equipment is available, according to specifications given below.



Trihedral Reflector - Isoceles Triangles



Mounting Bracket

A = 4.4 inches
B = 3.0 inches
C = 4.3 inches

$$\sigma = \frac{4\pi(0.289\ L^2)^2}{\lambda^2} \longrightarrow L = \left(\frac{\sigma\lambda^2}{4\pi(0.289)^2}\right)^{1/4}$$

The maximum radar cross-section (RCS) obtained on the symmetry axis is given by the above equation, where

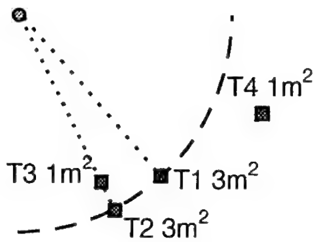
L = the length of each side of the reflector

λ = the wavelength [0.032 m]

0.28 = the fraction of the trihedral projected area that participates fully in the triple reflection process

For $\sigma = 1m^2$, L = 7.02 inches; and for $\sigma = 3m^2$, L = 9.24 inches.

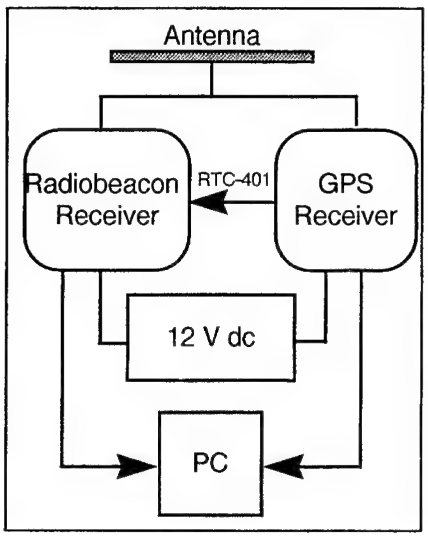
2. Mount FTRs with clamps on aluminum pipes of 4" diameter, and 6' length.
3. Mount pipes to 4' x 4' pieces of plywood, at a 12° angle to minimize radar return from the pipe, and take to the FTR area. (South of runway 1L)
4. Make sure FTRs have a direct line of sight to the antenna on the tower roof.
5. Make sure surrounding grass is cut to minimize ground clutter.
6. Stake one $3m^2$ (T1) target to ground.
7. Stake second $3m^2$ target (T2) a measured 80' away from T1, along constant radius.
8. Stake one $1m^2$ target (T3) a measured 40' in front of T2, aligned radially with tower.
9. Leave second $1m^2$ target (T4) mobile to resolve ambiguities. See figure below.



3.3 DGPS MEASUREMENT OF FIXED TARGET LOCATIONS

The precise lat/lon coordinates of the FTRs are obtained from Differential Global Positioning System (DGPS) measurements of their locations and listed in Table 3-5 (refer to Section 3.11).

1. Set equipment up following diagram below.



2. Set DGPS Radiobeacon Receiver as shown in Table 3-6.

Table 3-6. DGPS Receiver Settings.

Status	On-line operational testing
RBn Antenna Location (A)	43 00.1N, 087 53.3W
REFSTA Antenna Location (A)	43 00.15170N, 087 53.30641W
REFSTA Antenna Location (B)	43 00.14137N, 087 53.29261W
REFSTA RTCM SC-104 ID (A)	106
REFSTA RTCM SC-104 ID (B)	107
Broadcast Site ID	833
Transmission Frequency	297 kHz
Transmission Rate	100 BPS
RTCM Correction Message	TYPE-9
Morse Code Identifier	None [single carrier operation]
Signal Strength	75µV at 140 SM
Planned/Observed Outages	Off-air 0055Z 28 Sep to 0143Z 28 Sep 95 Off-air 211140Z 27 Sep to 2200Z 27 Sep 95

3. Set Global Positioning System (GPS) Receiver as follows:

   - "AutoLocate Mode" to force a search for a new set of satellites.
   - Enter your initial position in the format (hddd mm.mmm).
   - Map Datum (WGS-84)
   - CDI Scale
   - Units of Measure (Nautical)
   - Heading Reference (Auto Mag)

4. Set GPS antenna in middle of ASDE radar antenna array.
5. Power up system.
6. Check beacon status.
7. Set system for differential data collection.
8. Clear track log buffer when system reaches "3D Navigation" status.
9. Set collection criteria for every 10 seconds.
10. Check I/O criteria (RTCM/NMEA).
11. Collect data for 20 minutes.
12. Note ATCT position data.
13. Set Location as a waypoint ("MKE").
14. Set up system for "Track Log Transfer to PC."
15. Transfer data to PC (filename: tower.dat).
16. Average lat/lon data in tower.dat.
17. Check data against noted position data; **RECORD**.
18. Move antenna to target location.
19. Power up system.
20. Check beacon status with PC connection.
21. Set system for differential data collection.
22. Clear track log buffer when system reaches "3D Navigation" status.
23. Set collection criteria for every 10 seconds.
24. Set I/O criteria (RTCM/NMEA).

25. Note FTR position data (3 entries).

26. Collect data for 20 minutes.

27. Set Location as a waypoint ("TRn", n = 0 to 9).

28. Determine range and bearing from "MKE" waypoint (ATCT location).

29. Set up system for track log transfer to PC.

30. Transfer data to the PC (filename target_n.dat).

31. Average lat/lon data in target_n.dat.

32. Check data with the noted position data; **RECORD**.

33. Repeat steps 18 through 32 for other fixed targets (T2 and T3).

3.4 EQUIPMENT LIMITS

Many of the following tests involve the use of attenuator pads to prevent damage to the test equipment. As many different levels of attenuation were needed, the value was calculated for each item. This being the case, certain equipment limits were recorded below. Most, if not all, of the desired information can be found in the equipment manuals. System requirements are given below; data is shown in Table 3-7 (refer to Section 3.11).

1. Find maximum power input to the power meter; **RECORD**.

2. Find maximum power input to the oscilloscope; **RECORD**.

3. Find maximum power input to the frequency counter; **RECORD**.

4. Find maximum power input to the spectrum analyzer; **RECORD**.

5. Maximum power out of transmitter is 25 kW. Convert to dBm; **RECORD**.

6. Find manufacturer's value of dynamic range; **RECORD**.

7. Measure maximum power out of signal generator; **RECORD**.

3.5 TRANSMITTER AND RECEIVER MEASUREMENTS

The transceiver tests measure parameters specific to the transmitter (Sections 3.5.1–3.5.4) and receiver (Section 3.5.5). "Radio Spectrum Engineering Criteria" (Section 3.5.6) checks for any transmitting element outside this requirement; see also Appendix D. Sections 3.5.7 and 3.5.8 reveal information about signal transmission and reception. Section 3.5.9 measures the antenna radiation pattern for comparison to specified performance. These and all remaining tests are recorded in Table 3–8 (refer to Section 3.11). The transceiver control panel is illustrated in Figure 3-2, and the controls explained below.

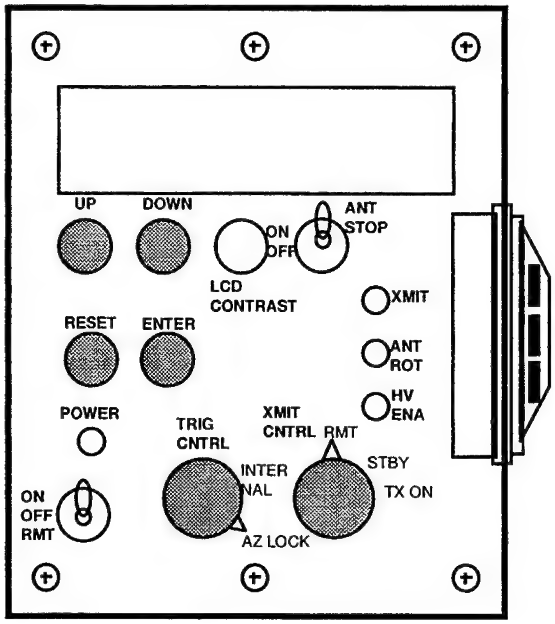


Figure 3-2. Transceiver Control Panel.

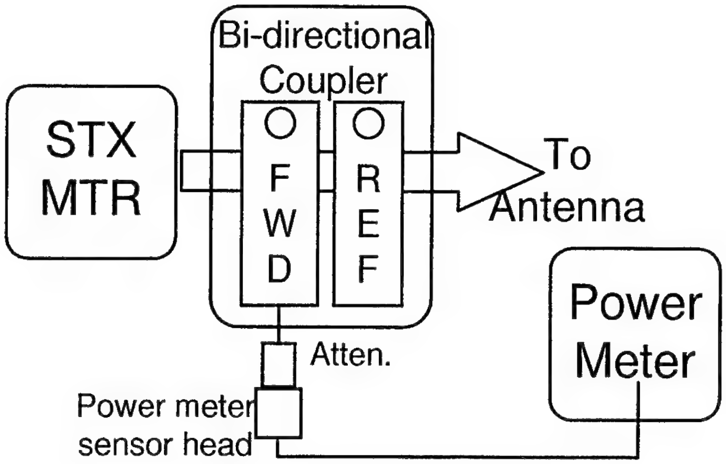
Key To Transceiver Control Panel

Up/Down	*[pushbuttons]:*	scroll up and down the LCD menu on the screen above.
LCD Contrast	*[dimmer switch]:*	controls brightness of LCD screen.
Ant Stop	*[toggle switch]:*	to stop power to the antenna in case of test purposes or emergency.
Reset/Enter	*[pushbutton]:*	Not in use.
XMIT	*[LED]:*	when ON indicates system is in transmit mode, i.e., RF energy emitting from array.
ANT ROT	*[LED]:*	inactive; slow start unit has active LED, when ON indicates antenna is rotating.
HV ENA	*[LED]:*	when ON indicates high voltage power is being supplied to transmitter.
Power	*[LED]:*	when ON indicates facility power is being supplied to transceiver.
ON/OFF/RMT	*[toggle switch]:*	ON/OFF supplies/cuts off facility power to system; RMT: inactive.
Trig[ger] Cntrl	*[knob]:*	AZ(imuth) LOCK for normal operations, INTERNAL for troubleshooting.
Xmit Cntrl	*[knob]:*	TXON commences RF transmission; ST(and)BY enables high power and magnetron warmup without actual transmission; RMT: inactive.

3.5.1 Peak Power Test

This test measures transmitter power, to compare actual output power with the manufacturer's specification. If these two values differ significantly, system adjustments should be reexamined.

1. Set equipment up following diagram below.



2. Subtract maximum input value for power meter from transmitter power output (see Table 3-7, refer to Section 3.11.) Subtract value of bi-directional coupler. As a safety factor, add enough dBm to this result to reach next attenuation level. Note value.

3. Verify appropriate attenuation and attach to setup.

4. Set MTR CNTRL switch to ON, TRIG CNTRL to INTERNAL, and XMIT CNTRL to TX ON.

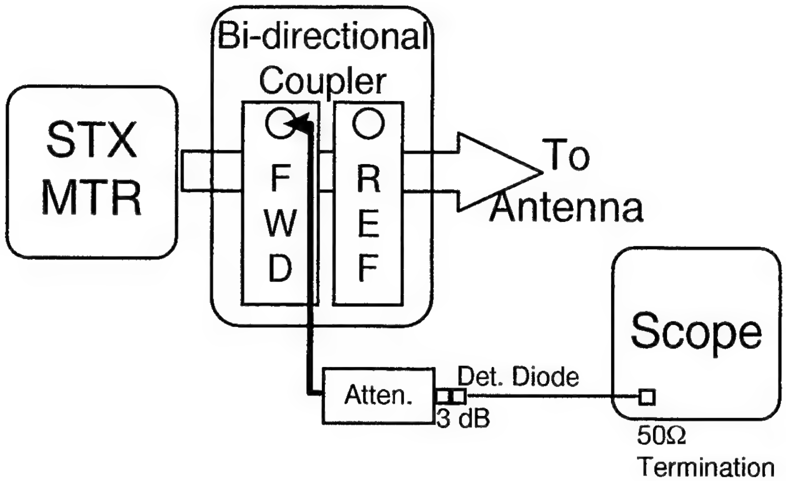
5. Add power meter reading, value of added attenuation (see Table 3-3, refer to Section 3.11), add value of bi-directional coupler; total and **RECORD**.

6. Videotape setup and results; **VIDEO.**

3.5.2 Pulse Width, Rise Time, and Fall Time Measurements

This test examines characteristics of the transmitted pulse. If these values differ significantly from the manufacturer's values, system adjustments should be examined.

1. Set equipment up following diagram below.



2. Subtract maximum input value for oscilloscope from transmitter power output (see Table 3-7, refer to Section 3.11). Subtract value of bi-directional coupler and cable. As a safety factor, add enough dBm to this result to reach next attenuation level. Note value.

3. Verify appropriate attenuation and attach to setup.

4. Set MTR CNTRL switch to ON, TRIG CNTRL to INTERNAL, and XMIT CNTRL to TX ON.

5. Set scope for channel 1, trigger internal, and so pulse is on screen.

6. Set pulse peak to center of horizontal graticule of the scope display.

7. Remove the 3 dBm pad.

8. Measure pulse width from where pulse rising edge crosses the center graticule to where the pulse falling edge crosses it; **RECORD**. (pulse width)

9. Videotape setup and results; **VIDEO**.

10. Adjust variable amplitude on channel 1 so pulse fills scope display marks 0 to 100.

11. Measure the time pulse takes rising from 10% line to 90% line; **RECORD**. (rise time)

12. Videotape setup and results; **VIDEO**.

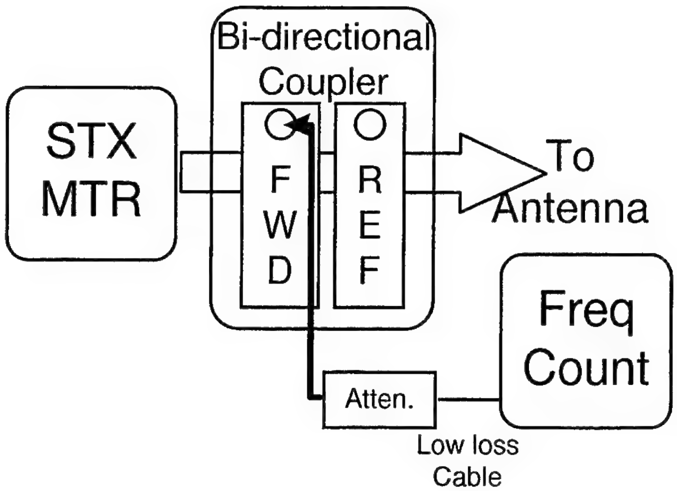
13. Measure the time pulse takes falling from 90% line to 10% line; **RECORD**. (fall time)

14. Videotape setup and results; **VIDEO**.

3.5.3 Frequency Stability Test

This test measures variance in the frequency of the transmitted pulse. If it varies significantly, it may be an indication that the magnetron may need to be replaced, or readjusted.

1. Set equipment up following diagram below.



2. Subtract maximum input value for frequency counter from transmitter power output (see Table 3-7, refer to Section 3.11). Subtract value of bi-directional coupler and cable. As a safety factor, add enough dBm to this result to reach next attenuation level. Note value.

3. Verify appropriate attenuation and attach to setup.

4. Set MTR CNTRL switch to ON, TRIG CNTRL to INTERNAL, and XMIT CNTRL to TX ON.

5. **RECORD** frequency value displayed on frequency counter.

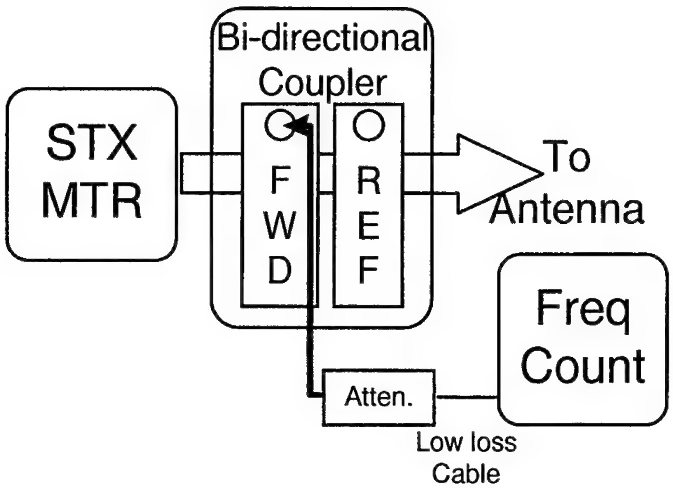
6. Subtract measured frequency from the manufacturer's listed frequency; **RECORD** the absolute value.

7. Videotape setup and results; **VIDEO**.

3.5.4 Pulse Repetition Frequency (PRF) Measurement

The PRF test is another test which, if it differs significantly from the manufacturer's specification, may indicate that transmitter adjustments are needed.

1. Set equipment up following diagram below.



2. Subtract maximum input value for frequency counter from transmitter power output (see Table 3-7, refer to Section 3.11). Subtract value of bi-directional coupler and cable. As a safety factor, add enough dBm to this result to reach next attenuation level. Note value.

3. Verify appropriate attenuation and attach to setup.

4. Set MTR CNTRL switch to ON, TRIG CNTRL to INTERNAL, and XMIT CNTRL to TX ON.

5. Select PRF function on the frequency counter. (Press: Special 6,7, Period.)

6. **RECORD** PRF value.

7. Videotape setup and results; **VIDEO**.

3.5.5 Minimum Discernible Signal (MDS) and Dynamic Range Tests

The MDS test is an indication of the smallest signal that the receiver can tell is a target. This information is necessary to determine the dynamic range of the system. A safety precaution warning and safeguard is included in Step 1. The tests are repeated with the signal generator pulse width set at 40 nsec.

MDS Test

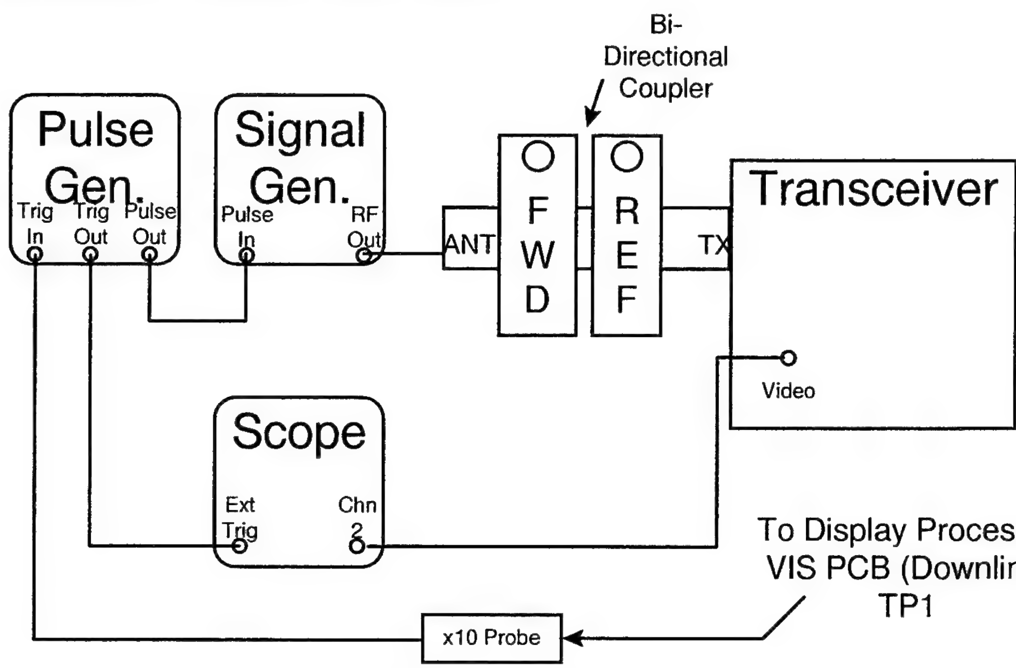
1. Turn off radar system and **DISCONNECT MAGNETRON FILAMENT CONNECTION!** [Disconnect the BNC-type connector with the filament at the magnetron; it is the white cable coming from the modulator board through the transceiver cabinet to the magnetron.]

2. Place MTR CNTRL switch on MTR Control Panel to ON.

3. Disable AFC of the OFF-LINE receiver by setting SW1 and SW2 to the right, SW3 to the left on the AFC Sense PCB.

4. Remove J7 (STC) on Controller PCB.

5. Set equipment up following diagram below.



6. Set signal generator to 9375 MHz, CW mode. Set signal generator output power controls to 0 dBm.

7. Set trigger controls (level and polarity) of pulse generator to trigger on positive trigger portion of the downlink video.

8. Set oscilloscope controls to trigger on positive trigger output of pulse generator.

9. Set signal generator to pulse mode, and adjust pulse generator for pulse width of 0.25 μs.

10. Set pulse generator delay control to produce a pulse delayed 5 μs from trigger. The RF pulse should now appear in downlink video at 5 μs from start of the sweep.

11. Adjust oscilloscope controls so that RF pulse can be viewed using a time base of 1μs per division on oscilloscope.

12. Adjust signal generator frequency in increments of 0.25 MHz or less to peak response of RF pulse on downlink video.

13. Check for Minimum Discernible Signal (MDS), by viewing RF pulse on oscilloscope and reducing RF output of signal generator until pulse just blends with the noise floor.

> **NOTE**
> To aid in signal detection, use the pulse delay control to vary the pulse delay slightly. MDS is reached when a 1 dBm change in RF output attenuator causes the signal to no longer be identifiable in the noise.

14. Read the RF level on the signal generator. **RECORD** MDS.

15. Videotape setup and results; **VIDEO**.

Dynamic Range Test

1. Increase the signal generator power output by the amount equal to the specified dynamic range (see Table 3-7, refer to Section 3.11), minus a reference margin of 3 dBm.

2. Note the amplitude of the video signal on the oscilloscope.

3. Increase the signal generator power output by 3 dBm.

4. Verify that amplitude of the video signal on oscilloscope increases by at least 25%.

5. Continue increasing signal generator output level in 3 dBm increments until the video signal amplitude saturates and increases less than 25%.

6. Determine the maximum signal generator output that will yield a 25% increase in video amplitude. This is done by checking the 25% increase for a 3 dBm increase between the current signal generator reading, and the last reading to give a nonsaturated increase.

> For example, an increase from -13 dBm to -10 dBm gave a 25% increase. Then an increase from -10 dBm to -7 dBm saturated, and did not give a 25% increase. Check -12 to -9 for a 25% increase. If it saturates, the dynamic range is -10 dBm - MDS. If it does not saturate, check -11 to -8 for a 25% increase. If it saturates, the dynamic range is -9 dBm - MDS. Otherwise it is -8 dBm - MDS.

7. Calculate dynamic range; **RECORD**.

8. Videotape setup and results; **VIDEO.**

9. On the AFC Sense PCB, place AFC SW1 and SW2 to the left, place SW3 to the right.

10. Place MTR CNTRL to OFF and connect magnetron filaments.

11. On MTR Control Panel, switch XMIT CNTRL switch to RMT.

12. On MTR Control Panel, switch CNTRL switch to ON.

40 nsec Pulse Width Test Repetitions

1. Set signal generator pulse width to 40 nsec.

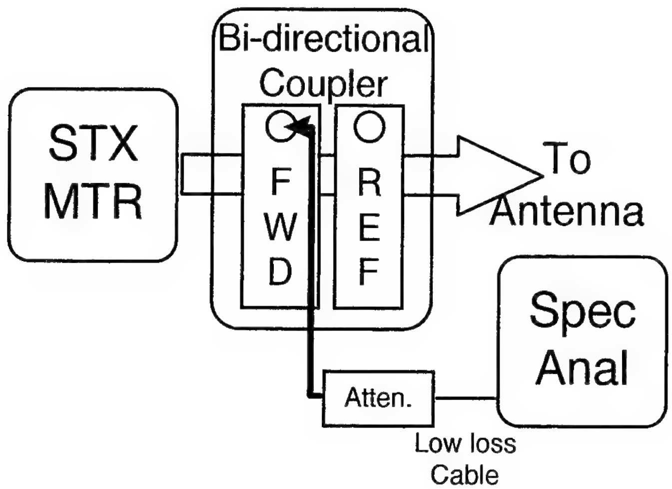
2. Repeat both MDS and Dynamic Range tests.

3.5.6 Radio Spectrum Engineering Criteria (RSEC) Test

The wide application of radar for various functions makes large demands on the electromagnetic spectrum and requires that the Federal Communications Commission (FCC) apply effective frequency management measures on all radio equipment and systems. To better manage the Radio Frequency Spectrum, the FCC has established the radio frequency spectrum standard (RSEC), a criterion that limits spectrum-related parameters and characteristics of radio systems.

NOTE: Absent expected value and what is passing.

1. Set equipment up following diagram below.

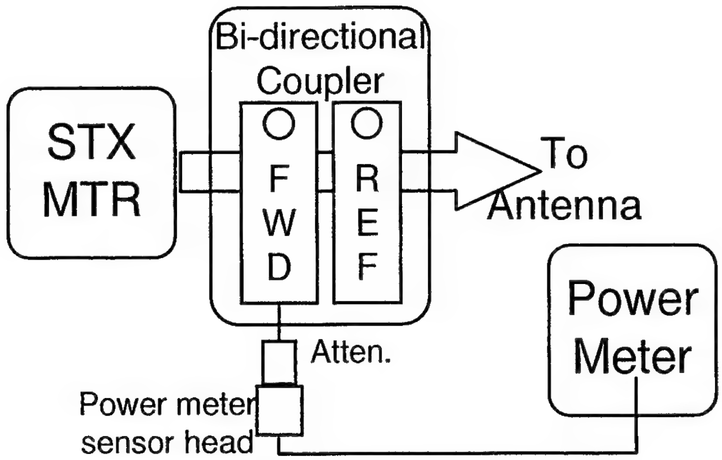


2. Subtract maximum input value for spectrum analyzer from transmitter power output (see Table 3-7, refer to Section 3.11). Subtract value of bi-directional coupler and cable. As a safety factor, add enough dBm to this result to reach next attenuation level. Note value.
3. Verify appropriate attenuation and attach to setup.
4. Set MTR CNTRL switch to ON, TRIG CNTRL to INTERNAL, and XMIT CNTRL to TX ON.
5. Use "peak find" function to get to the peak of the signal.
6. Optimize signal on spectrum analyzer display.
7. Note the frequency below peak that is -40 dBm from the peak.
8. Note the frequency above peak that is -40 dBm from the peak.
9. Calculate frequency span by taking difference of previous two noted values, using equations given in Appendix D; **RECORD**.
10. Videotape setup and results; **VIDEO**.

3.5.7 Voltage Standing Wave Ratio (VSWR)

The VSWR test determines how well matched the waveguide system is with the antenna. A high VSWR may indicate a poor connection between transmitter and antenna.

1. Set equipment up following diagram below:



2. Subtract maximum input value for power meter from transmitter power output (see Table 3-7, refer to Section 3.11). Subtract value of bi-directional coupler. As a safety factor, add enough dBm to this result to reach next attenuation level. Note value.
3. Verify appropriate attenuation and attach to setup.
4. Set: MTR CNTRL switch to ON; TRIG CNTRL to INTERNAL; XMIT CNTRL to TX ON.
5. Note the forward power.
6. Add values of coupler and added attenuation to noted forward power value; **RECORD**.
7. Reconnect power meter and attenuation to reflected port of the bi-directional coupler.
8. If the signal is not visible, remove attenuation in increments **not greater than 10 dBm.**
9. Note the reflected power.
10. Add value of coupler and added attenuation to the noted reflected power value; **RECORD**.
11. Videotape setup and results; **VIDEO**.
12. Convert the values recorded in steps 6 and 10 to watts using:
$$\log^{-1} [(\text{dB}) / 10] \times 1 \text{ milliwatt.}$$
13. Calculate VSWR using following equation:
$$\frac{1+\sqrt{\frac{P_R}{P_F}}}{1-\sqrt{\frac{P_R}{P_F}}}$$
14. **RECORD** VSWR.

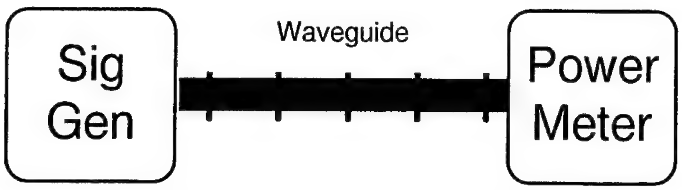
NOTE: Maximum acceptable VSWR for X-Band radar is 1.253:1, or a minimum return loss of 19 dBm.

3.5.8 Waveguide Insertion Loss Test

This test determines the signal losses of the waveguide system. A high loss may indicate a poor connection between transmitter and antenna.

NOTE: To perform these connections, switch ANT ROT to OFF (see Figure 3-2), and turn Safety Switch to OFF.

1. Set equipment up following diagram below.

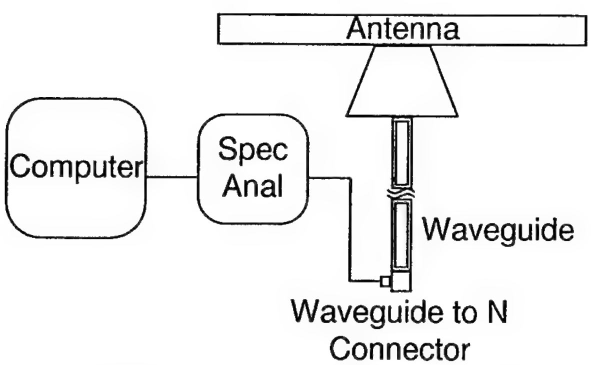


2. Set signal generator power to zero. Verify with power meter.
3. Measure power, then subtract all non-waveguide losses; **RECORD**.
4. Videotape setup and results; **VIDEO**.
5. Disconnect test equipment, setup system, and verify system operation.

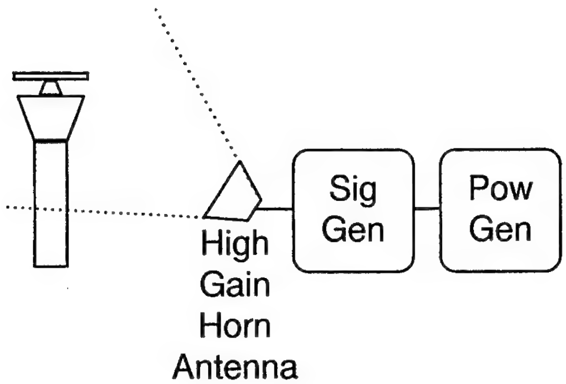
3.5.9 Antenna Radiation Pattern Measurements

This test measures antenna pattern characteristics (beamwidth and sidelobe levels) of the 18-foot, 0.45°, circular polarized antenna. In this test, the signal generator produces a CW RF signal, transmitted through a horn antenna aimed at the tower array. The horn antenna is oriented in both horizontal and vertical positions to obtain maximum polarization information. The ASDE antenna's sidelobe levels are critical: high sidelobe levels could cause multipath and clutter. Examples of results are shown in Figures 3-7 and 3-8.

1. Verify that the antenna is rotating at 60 RPM.
2. Set up tower equipment as follows:



3. Turn on spectrum analyzer, and observe noise floor level for a variety of frequencies in the operating frequency band.
4. Select a field position that produces minimal multipath effects.
5. Set up field equipment as follows:



6. Set signal generator to maximum power setting (+12 dBm, frequency of 9.375 GHz.)
7. Mount antenna to a stand in its horizontally polarized position (long edge of horn parallel to ground) and tilt its beam upward to encompass the ASDE antenna.
8. Tune spectrum analyzer to center frequency of 9.375 GHz and frequency bandwidth of 0 Hz.
9. To capture sidelobe patterns, operate spectrum analyzer like an oscilloscope, i.e., with time, not frequency, along the abscissa (y-axis) in a single sweep.
10. Set analyzer to trigger on the video input signal.
11. Capture spectrum analyzer beam pattern display, identified by setup parameters, and store in PC as individual files.
12. Calculate main beamwidth and sidelobe levels; **RECORD.**
13. Repeat measurements with the horn antenna mounted in its vertically polarized position (short edge of horn parallel to ground) and tilt its beam upward to encompass the ASDE antenna.
14. Capture spectrum analyzer beam pattern display, identified by setup parameters, and store in PC.
15. Calculate main beamwidth and sidelobe levels; **RECORD.**
16. Verify that horizontal and vertical tests show no significant profile differences. (Since the ASDE antenna is circular polarized, none are anticipated.)
17. Repeat both horizontal and vertical tests to check whether results are consistent.
18. Videotape setup and results; **VIDEO.**

3.6 SYSTEM MEASUREMENTS

3.6.1 Antenna Safety Switch Test

This test checks that the safety switches in the system work correctly. If switches do not work there is potential for danger, such as a technician being hit by moving antenna while working on the system.

1. Set MTR CNTRL switch to ON, TRIG CNTRL to INTERNAL, and XMIT CNTRL to TX ON.

2. Verify system is transmitting signal by observing display monitor.

3. Put antenna safety switch in OFF position.

4. Observe antenna for rotation, and display monitor for target returns. If antenna is not rotating, and there are no radar returns, **CHECK** data sheet.

5. Put antenna safety switch in ON position.

3.6.2 Current and Voltage Measurement

This test measures the current and voltage drains from the system equipment. It is a check on system efficiency and power dissipation levels.

1. Have system working under normal operating conditions, with no accessory equipment connected into auxiliary outlets.

2. Remove covers from Critical Power Facility and Power Distribution Panel (PDP).

3. Verify wiring is properly marked between panels (see Figure 3-1).

4. Measure voltages at PDP Main Circuit Breaker (CB) (A to B, B to C, and C to A); **RECORD.**

5. Measure current at PDP, Phases A, B, C; **RECORD.**

3.6.3 Acoustical Noise Test

This test measures the noise produced by the system when it is in normal operation, and when it is off. If the noise value is too high, measures must be taken to reduce it. Measurements were taken at 3 AM, when minimal noise was being produced in the environment. Since the airport is never closed, it was not possible to take measurements with all systems off.

1. Set noise meter to following settings:

SLM Calibration:	1 kHz signal of 94 dBm
Measuring range:	10 - 90 dBm
Frequency weightings:	A.

2. Turn radar system off.

3. Measure environment from center of the room at least 5' from the radar monitor; **RECORD.**

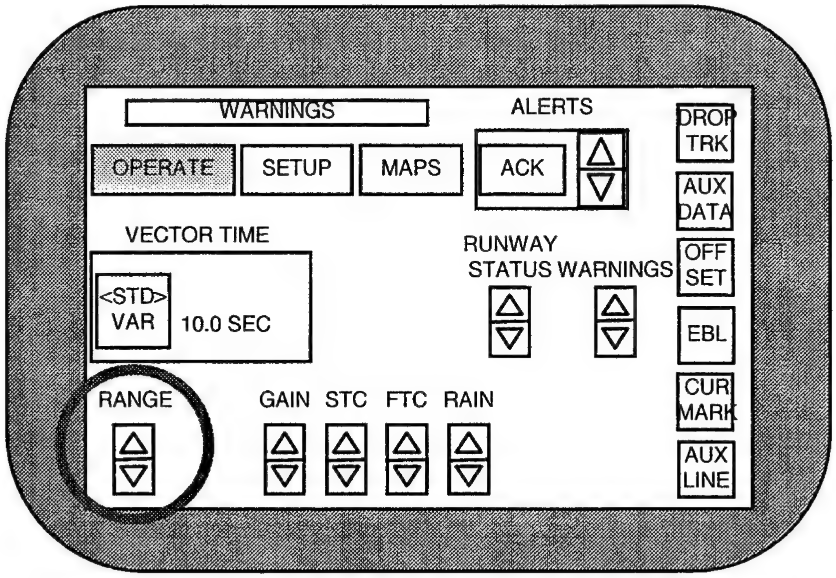
4. Turn system on and re-measure; **RECORD.**

3.7 RADAR ALIGNMENT TO FTR

3.7.1 Range Scale Demonstration

This test shows the different range scale settings the system can accommodate.

1. Touch screen in diagram below was used to make range scale selection.



2. The range adjustment was made by selecting the up or down arrow under the RANGE command. Change range scale, and observe display; **CHECK.**

3.7.2 FTR Alignment

This test demonstrates adjustment of FTRs on the airport surface. This procedure required two technicians, communicating via cellular phones; one in the field adjusts the FTR, one in the tower cab observes the FTR returns on the display.

1. Turn all FTRs away from ATCT to determine that no energy is being reflected from the poles (target stands).

2. Focus each FTR independently, starting with Target 1 (T1).

    - Loosen the clamp holding the trihedral to the pipe.
    - Adjust the height or angle of the FTR, in increments of 1/4" and 1/8".
    - Tighten the clamp and move away from the target.
    - When field technician moves a sufficient distance (100') from the target, the tower technician waits for three radar sweeps before making an observation.
    - Observe target strength and request FTR readjustment as needed via phone.

3. **CHECK** data sheets.

4. Repeat steps 2 and 3 for both T2 and T3. (The mobile T4 is not checked.)

3.7.3 Radar Registration Demonstration

This test verifies that the system displays the correct bearing and range of a target. The target position was measured with DGPS (see Section 3.3 above).

Antenna Offset Test

1. Set MTR CNTRL switch to ON, TRIG CNTRL to INTERNAL, and XMIT CNTRL to TX ON.
2. At the START-UP PAGE on the touch pad, select ENTER TESTS.
3. Use track ball and finger buttons to select test 5. CALIBRATION: VISUAL.
4. Select the Antenna Offset menu option using track ball.
5. Use RANGE and OFFSET selections to view optimum range of FTR T1 on airport field.
6. Note T1 bearing as displayed on the monitor.
7. If T1 does not match DGPS value (see Table 3-5, refer to Section 3.11), adjust to correct position as follows:
    - Find T1 on the radar display.
    - Place cursor on the target and press ENTER.
    - Observe the cursor bearing readout and move the cursor to correct bearing. The target reference line will remain at the target's location.
    - Press ENTER. The radar picture rotates so that T1 is at the correct bearing.
8. Return to normal video display; **CHECK**.

Zero Range Test

1. Set MTR CNTRL switch to ON, TRIG CNTRL to INTERNAL, and XMIT CNTRL to TX ON.
2. At the START-UP PAGE on the touch pad, select ENTER TESTS.
3. Use track ball and finger buttons to select test 5. CALIBRATION: VISUAL.
4. Select the Zero Range menu option using track ball.
5. Use RANGE and OFFSET selections to view optimum range of FTR T1 on airport field.
6. Note T1 range as displayed on the monitor.
7. Observing the cursor readout, move cursor to correct T1 range.
8. Press ENTER. A ring will appear at the selected range .
9. Move the trackball to position T1 video so that it rests on the inside leading edge of the ring and press ENTER.
10. Return to normal video display; **CHECK**.

3.8 DISPLAY MAP GENERATION

This test demonstrates how to make a map, both generally, and specifically for the airport. Since only two maps can be saved, it also shows how to save a created map.

For the airport map:

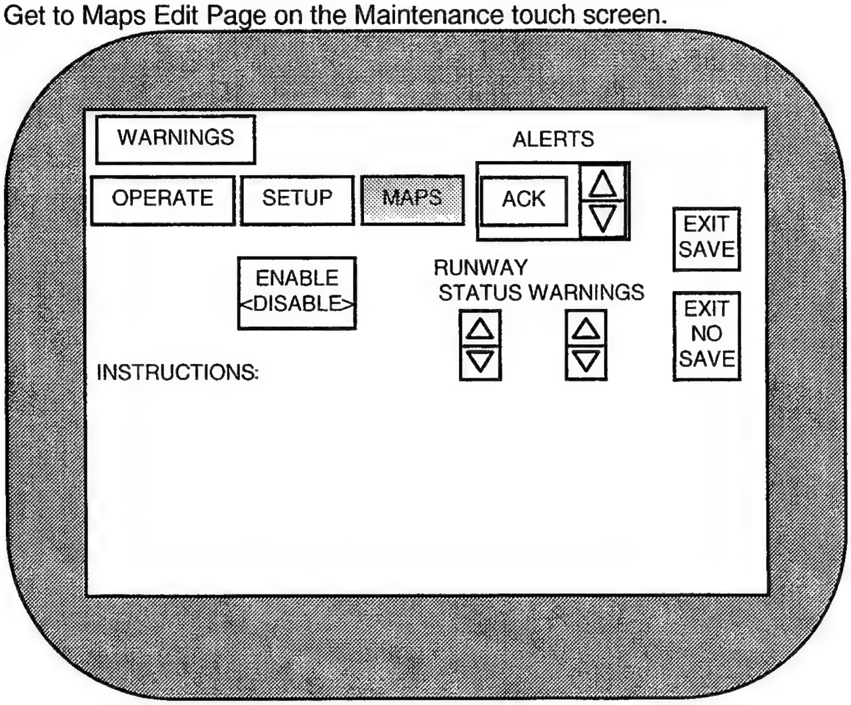
1. Create a pre-layout sequence for drawing the runways and taxiways.
2. Consult with AT personnel for critical taxiways.
3. Adjust settings for good view of runway and taxiway outlines on monitor.
4. Draw runways and taxiways, but let no polygon lines cross runway intersections.
5. Have AT personnel review finished map.
6. Work with AT personnel, using airport vehicle, to align airport map.

   Follow these guidelines to make an accurate map:

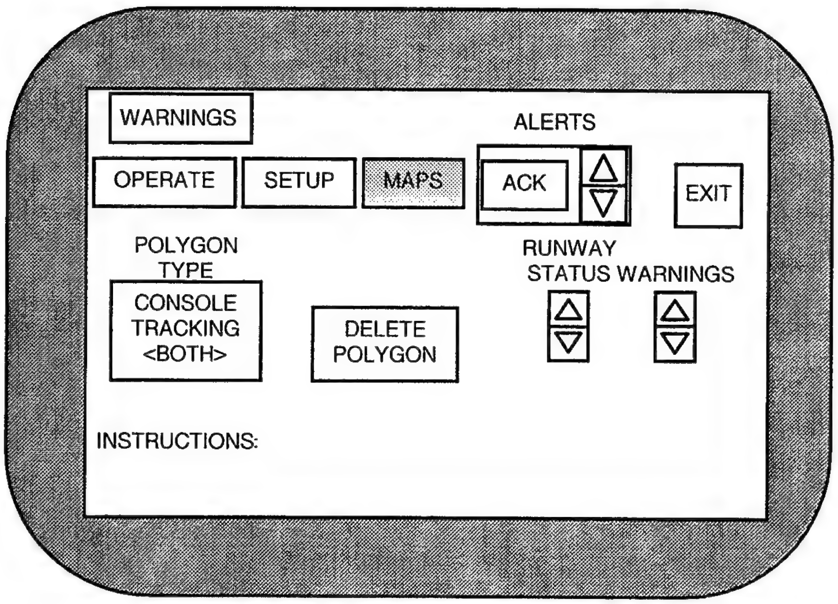
   - Start with the runway ends first.
   - Match up the vehicle with each corner of the runway.
   - Line up runway and taxiway intersections using the same method.
   - Make final decision on critical taxiways.
   - Store the final map.
7. **CHECK** data sheets when completed.

For the airport masks:

1. Get to Maps Edit Page on the Maintenance touch screen.



2. Use cursor and ENTER key to draw outline for new polygons.
3. To select polygon: press ENTER with cursor on a polygon line.
4. To move point: press ENTER with cursor on point, move and hit ENTER.
5. To delete line or add point: press CANCEL with cursor on polygon line.
6. To close polygon: press ENTER key over first polygon point.
7. Select ENABLE/DISABLE to toggle viewing previous mask.
8. When done select either EXIT SAVE to replace previous mask, or EXIT NO SAVE to retain previous mask.



9. Set POLYGON TYPE for the selected polygon.
10. Press DELETE POLYGON to remove selected polygon and exit page.
11. Press EXIT to exit page and deselect polygon.
12. **CHECK** data sheets when completed.

3.9 RANGE AND AZIMUTH RESOLUTION DEMONSTRATION

The range and azimuth resolution demonstration shows how well the radar system distinguishes targets. It also shows how close multiple targets (in this case, FTRs) can be before they fuse misleadingly into a single target. These procedures require at least two operators: one in the field, and one in the ATCT.

Azimuth Procedure

1. Turn T3 away from ATCT to avoid target returns on display.
2. Check whether T1 and T2 images on display are both visible and separate.
3. If yes, go to step 8.
4. If not visible and separate, try to achieve separation by refocusing targets. If targets become visible and separate, go to step 8.
5. If not visible and separate, turn T2 away from ATCT, locate T4 (portable FTR) 5' west of T2 (along the T1 - T2 azimuth) and focus T4.
6. Check whether T1 and T4 images on the display are both visible and separate. If yes, go to step 7. If no, move T4 west of T2 (i.e., away from T1 along their azimuth) in 5' increments, refocusing T4 at each move, until the images separate.
7. Move T4 east toward T2 in 1' increments, refocusing T4 at each move, until images merge. Go to step 8, adding 1'. Note the measured value.
8. Measure with a 100' tape-measure the distance between the targets in question; **RECORD**.
9. Videotape setup and results; **VIDEO.**

Range Procedure

1. Turn T1 away from ATCT to avoid target returns on display.
2. Check whether T2 and T3 images on display are both visible and separate.
3. If yes, go to step 8.
4. If not visible and separate, try to achieve separation by refocusing targets. If targets become visible and separate, go to step 8.
5. If not visible and separate, turn T3 away from ATCT, locate T4 (portable FTR) 5' north of T2 (along the ATCT - T2 radial) and focus T4.
6. Check whether T2 and T4 images on the display are both visible and separate. If yes, go to step 7. If no, move T4 north of T2 (i.e., away from ATCT along their radial) in 5' increments, refocusing T4 at each move, until the images separate.
7. Move T4 south toward T2 in 1' increments, refocusing T4 at each move, until images merge. Go to step 8, adding 1'. Note the measured value.
8. Measure with a 100' tape-measure the distance between the targets in question; **RECORD**.
9. Videotape setup and results; **VIDEO.**

3.10 MINIMUM COVERAGE DEMONSTRATION

This test showed the minimum distance from the antenna target can be detected. This procedure required the use of a vehicle.

1. View the radar screen, specifically looking at areas near the tower.
2. Select area closest to tower that is both free of clutter and accessible by vehicle.
3. Select EBL function on touch pad main page.
4. Have vehicle drive toward selected area.
5. Note where vehicle is last visible outside clutter.
6. Move cursor to last visible vehicle position.
7. Read range and bearing values from upper right corner of display; **RECORD.**

3.11 DATA SHEETS

Table 3-2. Equipment Calibration Checklist.

3.1.2 Equipment Item	*Calibrated*
Digital Voltmeter (DVM)	√
Ammeter attachment	√
Flow Meter	√
Frequency Counter	√
Noise Meter	√
Oscilloscope (Scope)	√
Power Meter	√
Sensor head	√
Pulse Generator	√
RF Signal Generator	√
Spectrum Analyzer	√
GPS Receiver	√
Radiobeacon Receiver	√
Power Supply	√

Table 3-3. Attenuator and Cable Calibration Values.

3.1.3 Calibration Item	*Value (dBm)*
Attenuator (30 dBm)	29.55
Attenuator (20a dBm)	20.4
Attenuator (20b dBm)	20.2
Attenuator (10 dBm)	10.1
Attenuator (3 dBm)	3.06
Cable 1	1.69
Cable 2	1.51
Black Cable	2.2

Table 3-4. System Checklist.

Section	*Checked*
3.1.4.1 Wiring	√
3.1.4.2 Links	√
3.1.4.3 Adjustments	√

Table 3-5. DGPS Lat/Lon Verification.

Description	*Latitude*	*Longitude*
3.3.17 ATCT	N 42° 56.868'	W 087° 54.380'
3.3.32 T1, $3m^2$	N 42° 55.746'	W 087° 53.920'
T2, $3m^2$	N 42° 55.743'	W 087° 53.937'
T3, $1m^2$	N 42° 55.756'	W 087° 53.943'

Table 3-7. Equipment Limits.

Test 3.4	*Value (dBm)*
Power Meter	20
Oscilloscope	20
Frequency Counter	10
Spectrum Analyzer	20
Transmitter	74
System Dynamic Range	60
Sig Gen max power out	12

Table 3-8. Functional Test Measured Values.[1]

Measured Item		Expected[2]	Actual	Check	Figure
3.5.1	Peak Power (dBm)	71.76	72.06		3-3
3.5.2	Pulse Width (nsec)	40 ± 8	45		3-4
	Rise Time (nsec)	10	9		3-4
	Fall Time (nsec)	30	28		3-4
3.5.3	Frequency (MHz)	9375	9379		
	Frequency Variance (MHz)	± 30	4		
3.5.4	Pulse Repetition Frequency (PRF) (Hz)	4096	4031		
3.5.5	Minimum Discernible Signal (MDS) (dBm)	-91	-98		
	40 ns (dBm)	-91	-90		
	Dynamic Range (dBm)	60	97		
	40 ns (dBm)	60	89		
3.5.6	Frequency Span (-40 dBm) (MHz)	358	233.8		3-5
3.5.7	Forward Power (dBm)	71.76	72.06		
	Reflected Power (dBm)	52.76	56.25		3-6
	Voltage Standing Wave Ratio (VSWR)	1.253:1	1.253:1		
3.5.8	Insertion Loss (dBm)	2	1.45		
3.5.9	Main Beamwidth (degrees, estimated)	.45	.4		3-7
	Sidelobe Level (dBm)	26	26		3-8
	Antenna Safety Switch			√	
3.6.2	A - B Voltage (v)		205		
	B - C Voltage (v)		208		
	C - A Voltage (v)		208		
	A Current (A)		3.5		
	B Current (A)		8.5		
	C Current (A)		3.5		
3.6.3	Acoustic Noise System Off		54.6		
	Acoustic Noise System On		56.7		
	Range Scale Demonstration			√	
3.7.2	FTR T1 Alignment			√	
	FTR T2 Alignment			√	
	FTR T3 Alignment			√	

1 Values remeasured on May 7, 1997 were Frequency (9377 MHz), PRF (4044 Hz), Frequency Span (202 MHz, and Forward Power (72.7 dBm).

2 Expected values by the manufacturer, with the sole exception of Frequency Span (3.5.6) which is the RSEC standard, calculated in Appendix D.

Table 3-8. Functional Test Measured Values. (cont.)

Measured Item			*Expected*	*Actual*	*Check*	*Figure*
	Antenna Offset				√	
	Zero Offset				√	
3.8	Map Generation				√	
	Mask Generation				√	
3.9	Azimuth Resolution (feet)		80	49		
	Range Resolution (feet)		60	51		
3.10	Minimum Coverage	range (nm)	.25	.25		
		bearing (deg)	–	330		

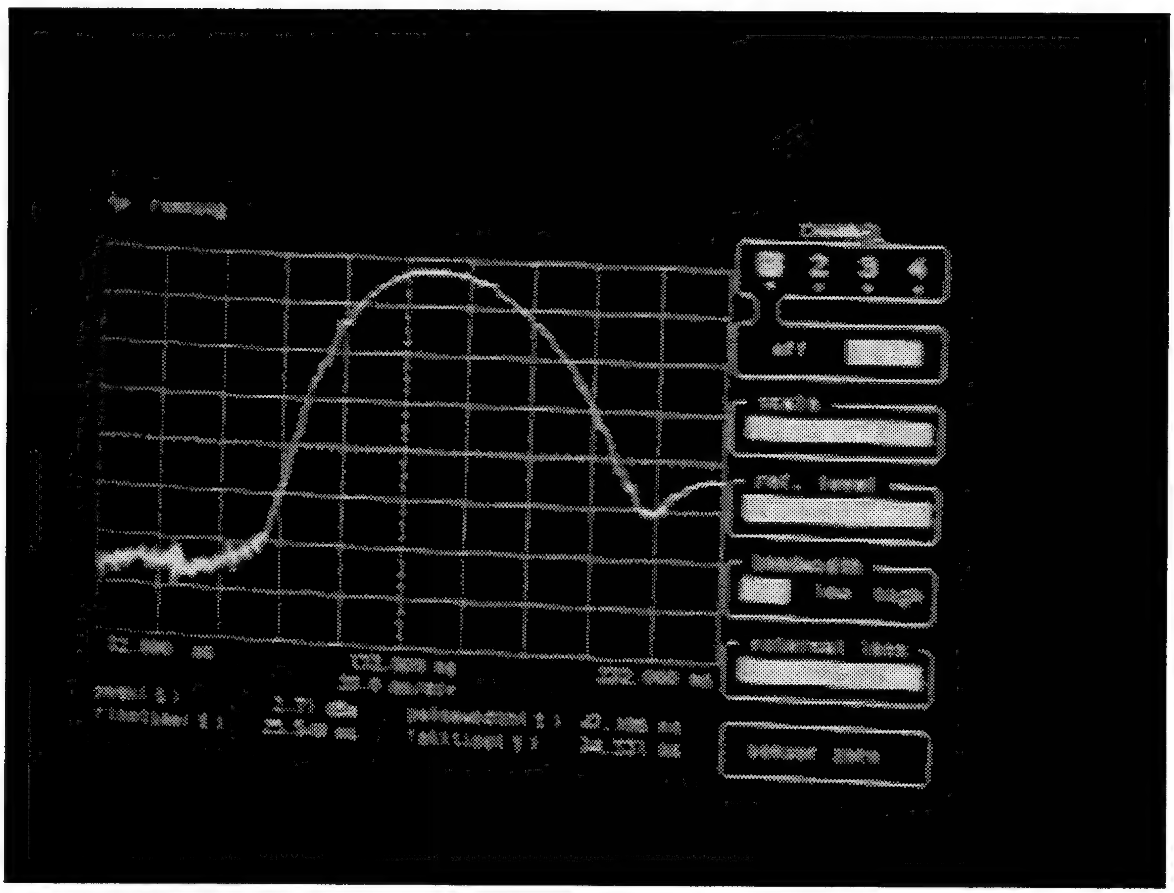


Figure 3-3. Peak Power Curve (dBm).

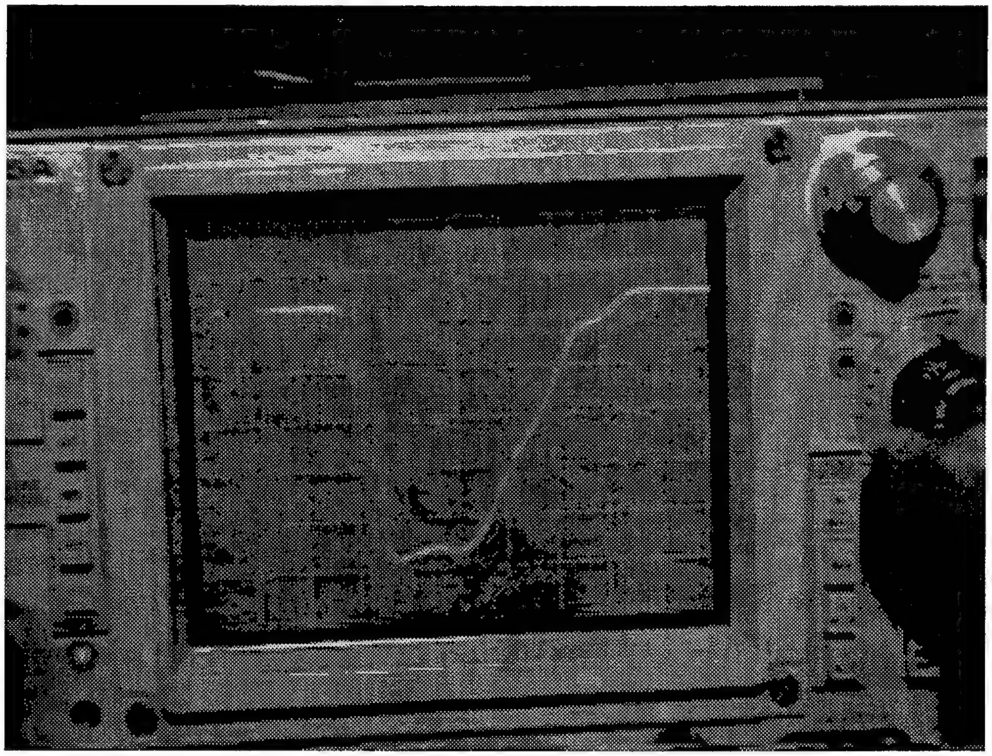


Figure 3-4. Pulse Width, Rise Time, and Full Time (nsec).

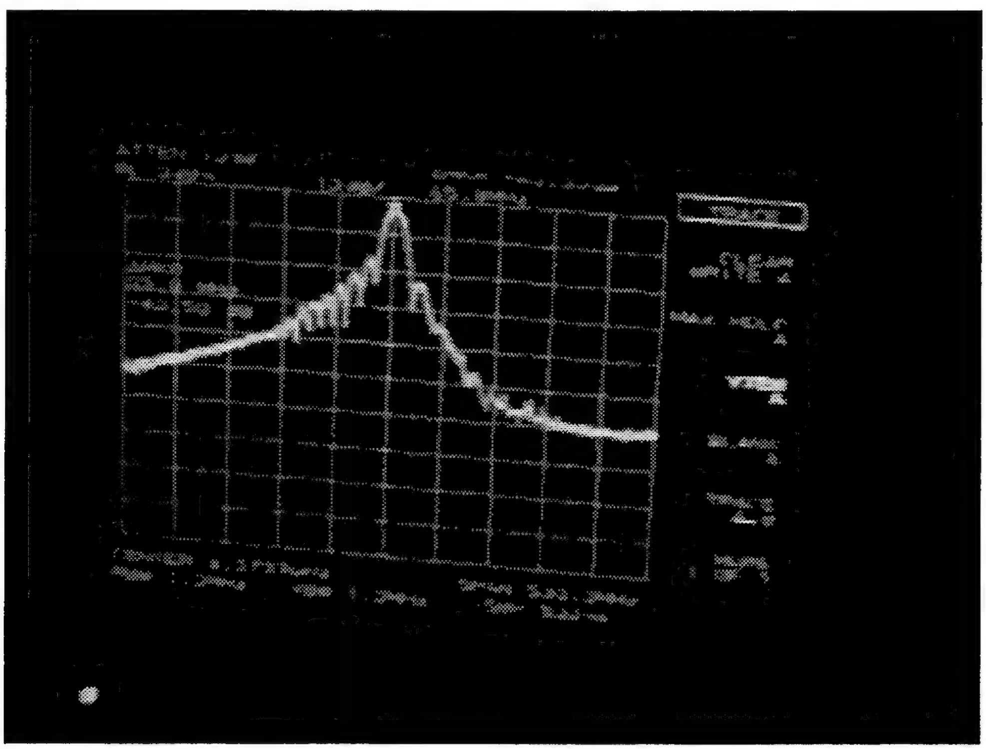


Figure 3-5. Frequency Span.

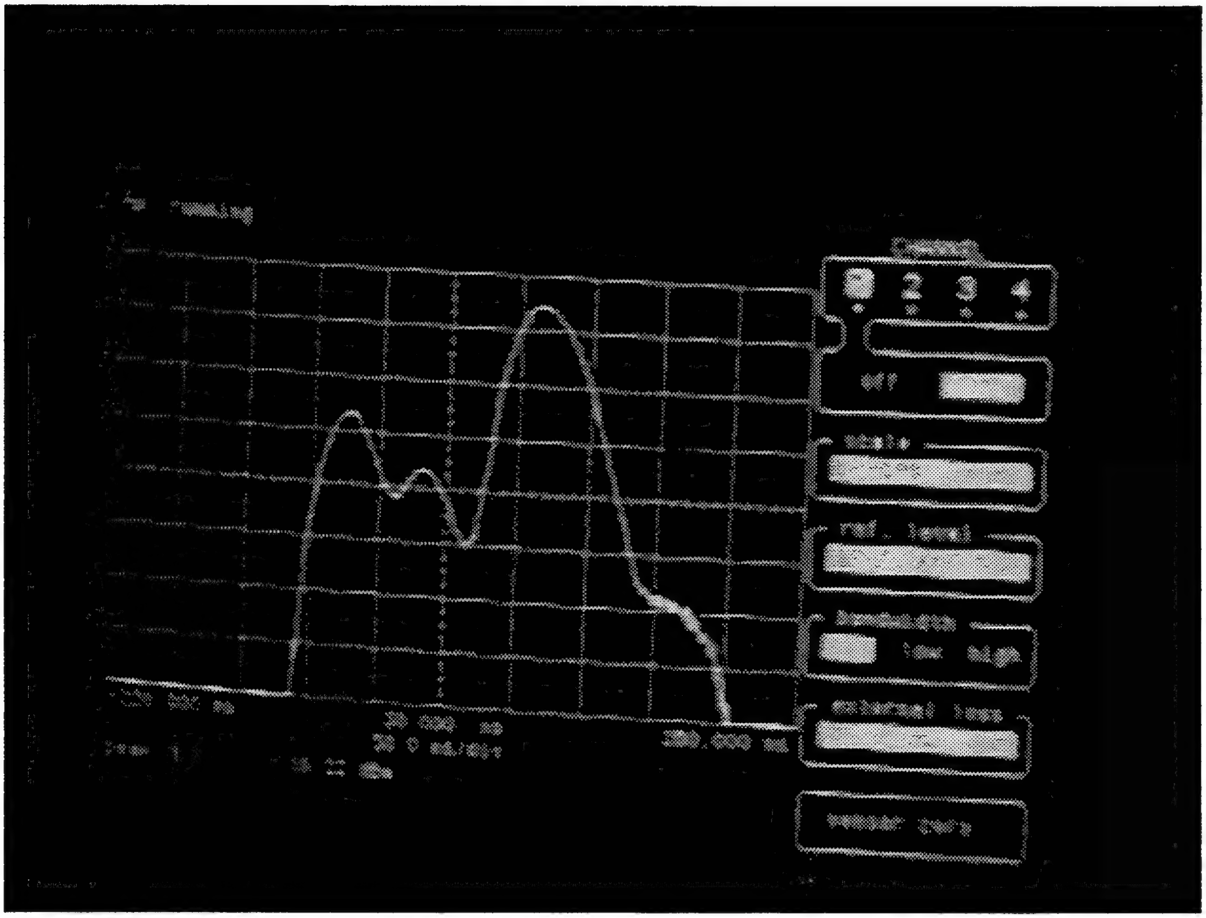


Figure 3-6. Reflected Power.

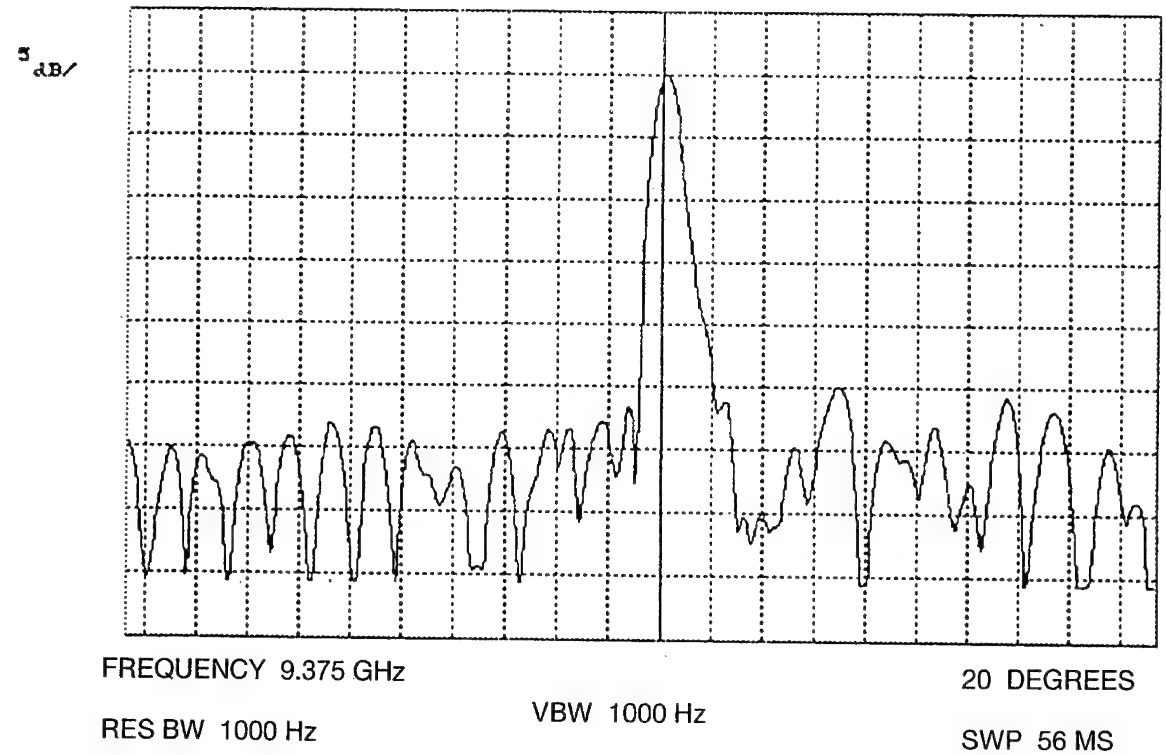


Figure 3-7. Antenna Pattern, Horizontal Polarity, 20°, Showing Sidelobes 25 dB Down.

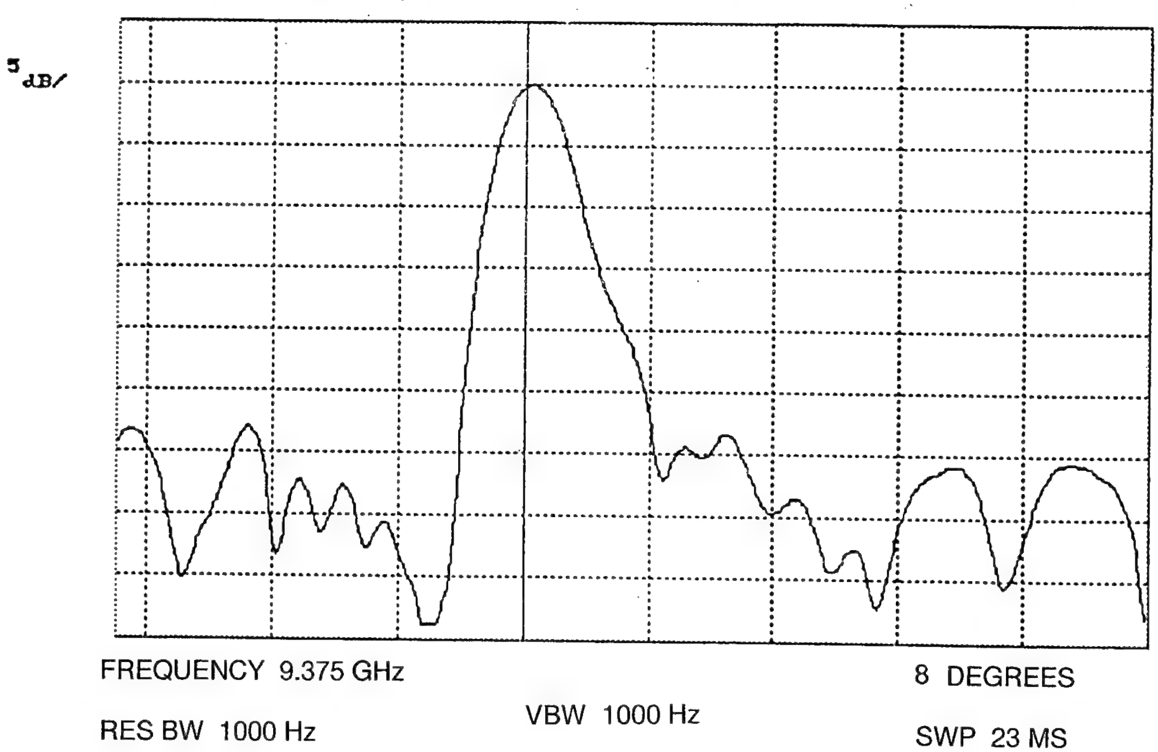


Figure 3-8. Antenna Pattern, Vertical Polarity, , Main Beam of .4 Degrees.

4. OPERATOR EVALUATION

The operator evaluation of the Low-Cost ASDE Radar, Phase II (Raytheon ASDE), at MKE was performed by local air traffic controllers. This evaluation afforded the FAA the opportunity to install and evaluate the radar, assess suggested enhancements and implement them, then re-evaluate the system at the same airport with the same personnel. Phase II enhancements of Phase I include: automatic radar tuning, increased range selection (in 1/4 nm increments), improved mapping features, masking capability, increased update rate, and a high brightness display.

The evaluation procedures capture the spirit of both ASDE-3 and Phase I operator test procedures. Consistency in the design and conduct of these tests enabled the test team to assess the differences and similarities of MKE's Phase I and II radars as they performed the nearly identical test battery under varied weather conditions.

The test team was made up of four members of MKE's ATC team: the NATCA low-cost ASDE representative (who doubled as test coordinator), the ATC training specialist, and the local NATCA president. The team performed exceptionally under very difficult conditions. In addition to the usual MKE traffic, the team had to cope with snow and ice storms that degraded the airport surface and added a fleet of snow removal vehicles to AT's surface operations. The radar system, moreover, was not fully optimized: two modulator failures during testing caused the display maps to become misaligned. Nevertheless, the test team was able to collect a wealth of data addressing both the system's ability to detect targets during a variety of typical airport operations and its effectiveness and suitability as a surface surveillance tool within the AT environment.

The operators' evaluation, originally scheduled for the week of December 16, was postponed to the week of January 26. System malfunctions prevented manufacturer certification and effective operator training. This delayed the building and registering of maps and the functional testing. Critical system problems included an unstable display presentation caused by a magnetron fan failure, ineffective display sensitivity controls caused by improper system alignment, and degraded range resolution caused by an out-of-specification pulse width. The team decided that the system's less critical shortcomings would be addressed after the evaluation.

By January 13, Raytheon had stabilized system operation by reducing the system's pulse width and aligning the system. Operator training and a limited functional evaluation were performed. Map registration, performed on January 23 and 24, was limited to runway ends, because availability of the county's test vehicle was limited by the severe weather conditons.

On January 26, the day before operational tests were to begin, a partial modulator failure of the system caused the airport map to become misaligned and the tune bar to malfunction. The maps were realigned, but not verified with an airport vehicle. The system failure's potential effects on false targets and position accuracy was explained to the test team. It was decided to proceed with testing, and to register the map at a later date.

During the test week, Milwaukee had a major snowstorm, which piled more snow onto airfields already covered with snow and ice. Returns from banked snow affected the quality of the radar's presentation. Icy runways and taxiways limited the testing of high-speed turnoffs.

On January 28, the modulator failed completely. The test team handcarried replacement parts from Raytheon in Manchester, NH. On January 29, the system was repaired and realigned. Operators' tests were restarted on January 30 and formal testing was completed on January 31. Informal testing under low visibility conditions was conducted *ad hoc* by controllers, filling out test forms on hand in the MKE ATCT between February and July of 1997.

This section discusses operator training and assessment, lists the operational tests, test personnel and equipment, test support and conduct, with comments on data presentation and safety precautions. The fourteen operational tests follow, with details of the procedure and the summary of the controllers' comments. Analysis of the test results–including comments on both the successes and positive features of the system as well as its malfunctions and shortcomings are detailed in Section 5.

Operator Training And Assessment

Raytheon trained MKE controllers to conduct the tests using the new radar. Training was hands-on, on-site, and real-time: sessions were held in the tower cab with instructor oversight using live targets. To assure effective training, two sessions were held, with two 'students' to one instructor. These four test controllers subsequently trained the remaining MKE controllers. At the end of the test plan, controllers found a one-page questionnaire to evaluate the training session itself. They were asked whether:

- all aspects of hands-on radar control for AT were covered adequately.
- the instructor was organized, giving clear explanations and answering questions.
- the manual supported and clarified all controls and functions.
- there were topics not covered well or remaining unclear.
- they learned all they needed to know to run and test the radar with confidence.

On the questionnaire (see page C-2), controllers suggested improvements in training effectiveness and rated training quality, using the following scale: *1 = Unsatisfactory, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent.* The average marks on each question on all four questionnaires was 4+.

Operational Tests

The test battery in the *MKE Phase II Operational Test Plan* is nearly identical to that of Phase I. The format remained the same, and one test was added, a human factors questionnaire on total system satisfaction (Test 13). The test battery is summarized below.

Test 1: Demonstration of Maximum Height Coverage. This test evaluated the height limitations of the system. Videotaped operations at various altitudes were useful to monitor target registration (Section 4.1).

Test 2: Demonstration of Shadowing with Dissimilar Sized Targets. This procedure tested for potential shadowing effects at various locations on the airport movement area. Shadowing may occur when a larger aircraft obscures the radar view of a smaller aircraft or vehicle (Section 4.2).

Test 3: Radar Registration of Targets on Runway Ends. This procedure tested system performance and usability viewing aircraft in hold position at runway ends (Section 4.3).

Test 4: Registration of Non-Aircraft Targets Traveling in Tandem. This procedure tested radar registration of non-aircraft targets traveling in tandem on the airport surface in typical airport operations (i.e., snow plows, maintenance vans, etc.) (Section 4.4).

Test 5: High-Speed Turnoff Demonstration. This procedure tested system performance in registering arriving aircraft making high-speed turn-off maneuvers. The test demonstrates system reaction as a target's aspect angle changes during the turn-off (Section 4.5).

Test 6: Radar Detection and Presentation. This procedure tested the potential delay in presentation as an approaching aircraft crosses the runway threshold. The procedure demonstrates the limits of the system due to the rotation rate of the antenna (Section 4.6).

Test 7: Target Display Presentation. This procedure tested radar presentation of targets of opportunity. Controllers, not involved in the formal testing contributed comments on forms left in the tower cab (Section 4.7).

Test 8: False Target Display Presentation. This procedure identified false targets displayed by the system. Videotapes backed up controllers' identification of false targets (Section 4.8).

Test 9: Position Accuracy Test. This test recorded the radar's relative map-to-target accuracy, covering all MKE movement areas. Controllers identified and recorded target location and quality on a map of the movement area. The procedure also identified potential problem areas associated with target registration (Section 4.9).

Test 10: Surveillance Update Rate. This procedure tested operators' visual identification of the system's update capabilities (Section 4.10).

Test 11: Probability of Detection. This procedure allowed operators to observe the system's probability of detection rate (Section 4.11).

Test 12: Display Satisfaction Test. This questionnaire gave AT an opportunity to critique system controls and features, and to assess improvements in the Phase II radar (Section 4.12).

Test 13: System Satisfaction Assessment. This questionnaire allowed controllers to critique the system in the tower cab environment while performing typical operations (Section 4.13).

Test 14: Low Visibility Presentation Test. This procedure tested the system under conditions of low visibility and precipitation during several months. Test forms left in the tower cab were filled in by controllers whenever adverse weather warranted. Data forms were recorded and assessed through July 1997 (Section 4.14).

Test Personnel and Equipment

Test Personnel

Test coordinator
Test observers / controllers (3)
Pilots of test planes
Drivers of county vehicles

Aircraft and Vehicles

Hawker Siddley 25 [Phillip Morris]
Cessna 150
Trucks, equipped with Ground Control Frequency (GCF) radio [County]
Van, GCF radio equipped [Airways Facilities]
Targets of Opportunity

Equipment

2 Fixed Target Reflectors (FTRs), 3^2 m
2 FTRs, 1^2 m
Scanner
Ground to Tower Communications (GCF)
Stop Watch
Video Recording Equipment
METAR code & Runway Visual Range (RVR) equipment [see Appendix B]

Test Support and Conduct

Test procedures 1 through 14 were performed at MKE from January 27 through 31, 1997. Low visibility operations (Test 14) were continued on an *ad hoc* basis from January through July, by having controllers fill out test forms on hand in the tower cab during periods of low visibility.

Controllers conducted the tests dynamically, adapting each test as weather and traffic conditions warranted. Targets of opportunity were used as available. The test coordinator reviewed test data as tests proceeded; if test objectives were not being met, procedures were modified and coordinated with the test team.

Controllers' preferences for system set-up and display, as well as their ideas regarding system applications for airport operations, were noted for potential modifications and enhancements to this and other ASDE systems.

In order to ensure proper system setup and to maintain standards of data collection, a test coordinator (FAA's National ASDE Representative (who doubled as an observing controller during tests)) and a team of observers (controllers) supported and conducted each test. Before the start of each test, the coordinator:

1. Verified that:

    - Radar had been operating at least 30 minutes before procedure began.
    - The FTRs were identified on the display.
    - The map was aligned for a full view of the test area.

2. Recorded the radar's current operating status.

3. Recorded current weather and visibility conditions (see below).

4. Established that radar was aligned to properly record the test, i.e., map setting, range setting, map alignment.

5. Established that the video recorder was operating, focused, recording display information, and was not interfered with during the test.

6. Made the test-specific fill-in sheets available to the test team.

7. With AT (and where applicable), established communications with test aircraft and/or vehicles and determined the safety of proceeding with the test (see Safety Precautions below).

8. Filled out a general pretest form prior to each test (see Figure 4-1 for a composite example) and updated it during the test, as weather and other conditions changed. Pretest forms include the following information:

    - ***Personnel and Equipment:*** Date, time, test team members' names, test vehicles used (aircraft or ground vehicle, when applicable).

    - ***Radar Information:*** Current operating settings, recordable on a fill-in bar graph, radar performance at various settings, and system reaction to operators' adjustments.

Operations Assessment of Raytheon Marine Radar
Located at General Mitchell International Airport

Test: ______________________________

Date: ____________ Time: ____________

Test Team: Coordinator: ____________

Observer: ____________

Observer: ____________

Pilot: ____________

Test Plane: Model: ____________ Make: ____________

Model: ____________ Make: ____________

Test Vehicle: Model: ____________ Make: ____________

Model: ____________ Make: ____________

Model: ____________ Make: ____________

Radar System Checks:

1. The radar has been operating longer than 30 minutes. ☐
2. The fixed targets have been identified. ☐
3. The map has been aligned for full view of the test area. ☐

Radar Settings:

TUNE ☐☐☐☐☐☐☐☐

GAIN ☐☐☐☐☐☐☐☐

RAIN ☐☐☐☐☐☐☐☐ INVERSE VIDEO ☐

FTC ☐☐☐☐☐☐☐☐ INVERSE VIDEO ☐

STC ☐☐☐☐☐☐☐☐ INVERSE VIDEO ☐

PULSE WIDTH ____________ RANGE SETTING ____________

Radar Presentation: ______________________________

Weather:

METAR: ______________________________

RVR: TD: ____________ MID: ____________ ROLLOUT: ____________

Visibility (ATC): ______________________________

Figure 4-1. Composite Pretest Form.

- ***Weather Conditions:*** Weather data was noted in two ways. METAR meteorological data was recorded by the coordinator before each test. Under low visibility conditions, controllers often added RVR and visual observations. (METAR and RVR concepts and notations are explained in Appendix B.)

Safety Precautions

AT had final responsibility for the safety of operations during these tests. They assessed ongoing AT operations and determined whether potential conflicts between testing and traffic warranted postponement of a test. AT and the test pilots determined whether a test needed to be halted or postponed for safety considerations, and reserved the right to continue, restart, or cancel any test that had to be postponed or terminated. Team members were cautioned to use extreme care on all aircraft movement areas during testing. All personnel and test vehicles within testing areas were equipped with radios.

Data Presentation

The test data in this report has been edited for clarity and conciseness. Test formats in the test plan had five parts--objective, schedule, list of personnel and equipment, setup, and procedure; schedule and setup have been omitted in the results. Before each test, the test coordinator filled out a boilerplate pretest form (see Figure 4-1); data from these forms have been summarized into Pretest Summaries. Surface condition information, taken from airport bulletins issued to pilots called Notices to Airmen (NOTAMS), is also appended for those tests (3 through 8) critically affected by snowstorms.

Test forms were designed for observer/controllers to record data (type, location, and quality) quickly and clearly, with space for comments encouraging them to write detailed remarks on radar performance; these have been interpreted and condensed in tabular form as Data Summaries. The MKE map also figured prominently in data recording, whether as a reduction and simplification of the whole airport (see Figure 4-2) or as isolated runway/taxiway segments under scrutiny during a specific test.

Video recordings of pertinent events, especially in tests tracking targets (e.g., Tests 1, 5 and 6) were made for documentation purposes. Images captured from the smaller maintenance display instead of the larger tower display may appear darker. Snapshots showing examples of target presentation appear in Sections 4 and 5.

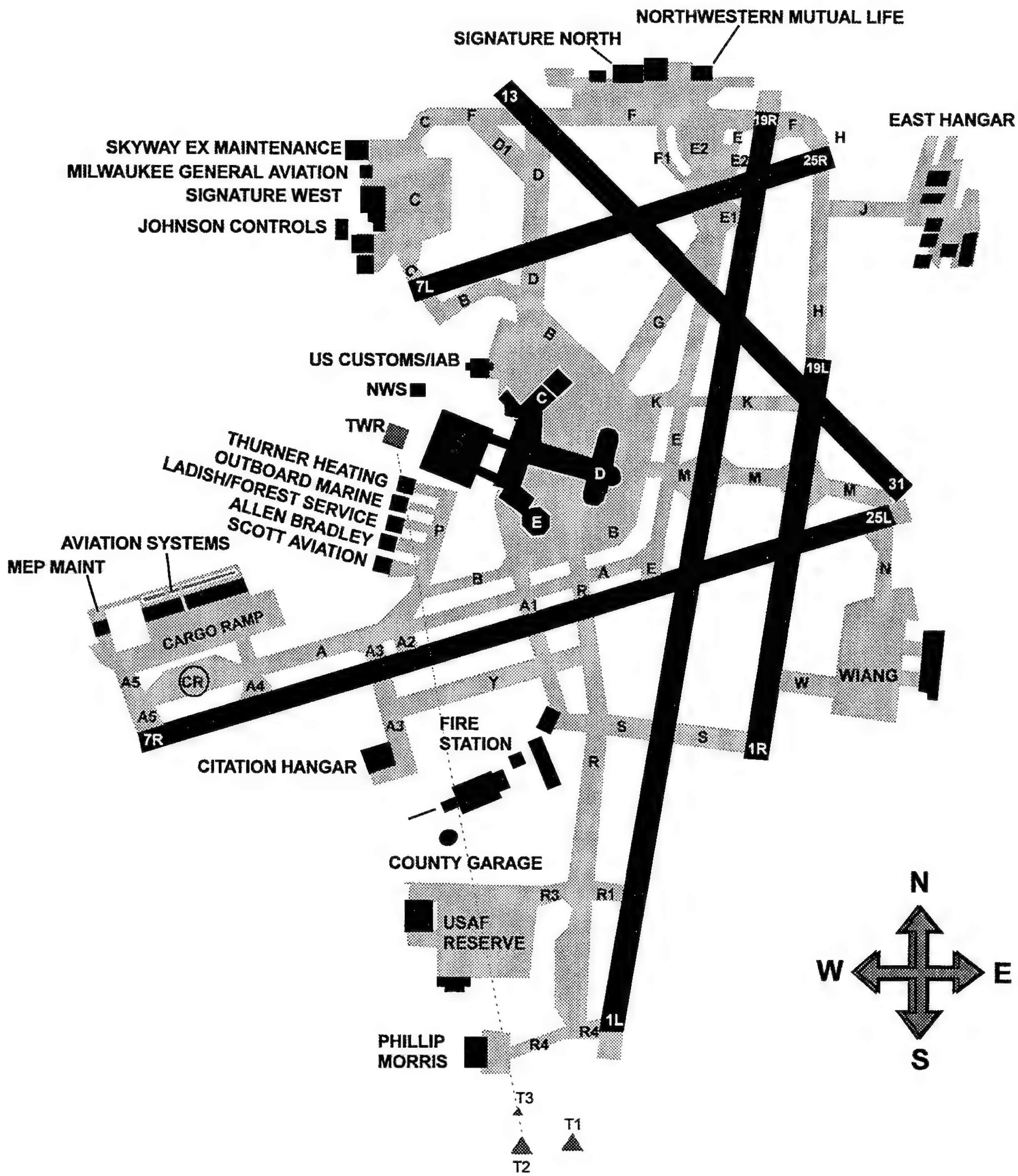


Figure 4-2. MKE Airport Map.

4.1 TEST 1: DEMONSTRATION OF MAXIMUM HEIGHT COVERAGE

This procedure tests the system's maximum height coverage above the airport surface area. The test is performed with flyovers on Rwy 19R - 1L by a Phillip Morris Hawker Siddley (HS25) Test Aircraft. The pilot flew at increasing altitudes associated with maximum height coverage at distances from 1/4 nm to 1 1/2 nm (see Figure 4-3). Tower observers recorded various target parameters (speed, altitude, registration) while the target was over the runway surface.

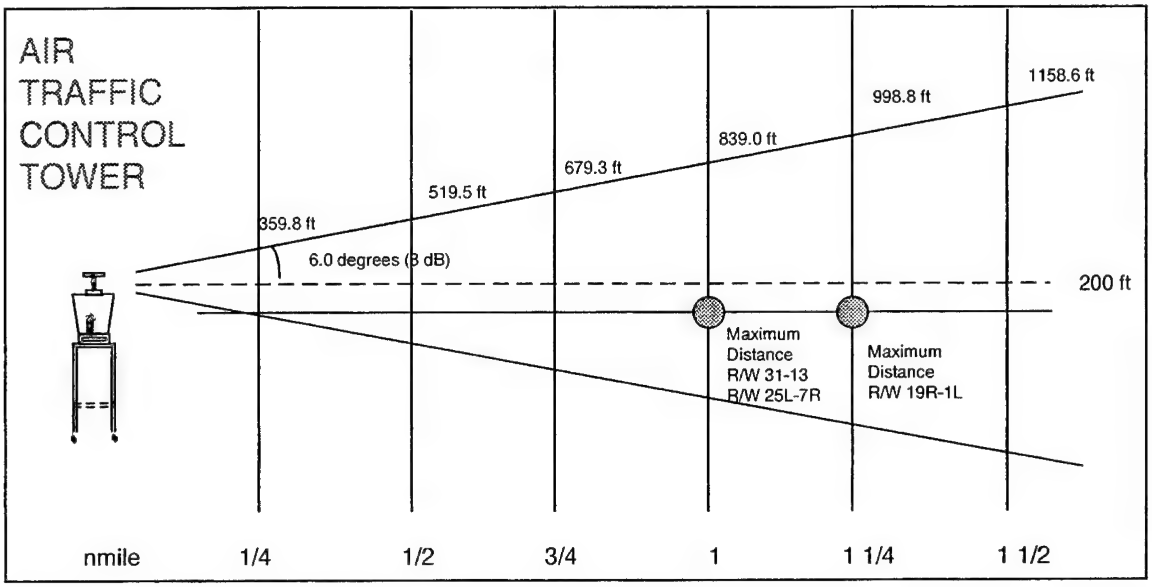


Figure 4-3. MKE ATCT, Showing Radar Vertical Coverage.

Procedure

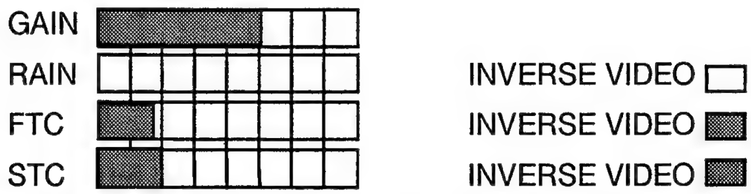
The pilot aligned the test aircraft with Rwy 19R - 1L and flew over it in successive passes at the following altitudes (in feet) above ground level (AGL): 200, 360, 520, 680, 840, 1000, 1160. The pilot verbally notified the tower when he was over each runway threshold. A team member audibly verified when the aircraft passed over each Rwy/Twy intersection. The team recorded:

- aircraft speed
- aircraft altitude
- visual detection of the target
- detection of the target on the display
- approximate location of the detected target on form's runway map
- the quality of the detected target.

Pretest Summary

Date: 1-28-97

Radar Settings [constant for all flyovers]:

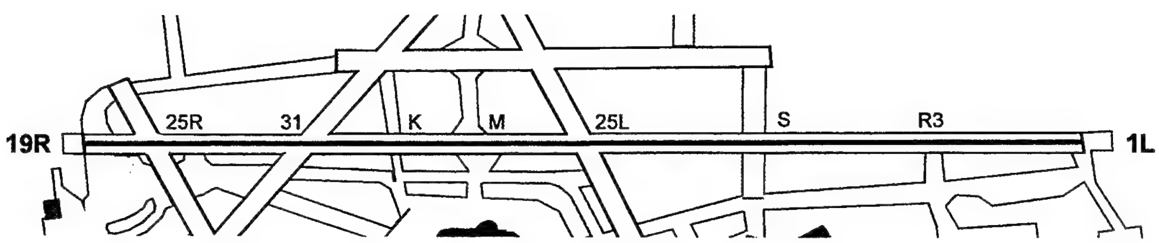


Weather: [METAR:] CLR 10SM [clear, visibility ten statute miles]

Data Summary

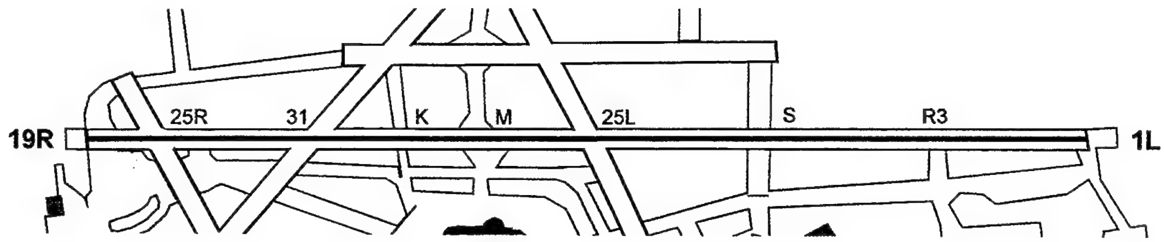
The HS25 made seven passes over Rwy 19R - 1L, increasing in altitude about 160 feet (100 meters) each pass. Targets appeared normal at 200 and 360 AGL, then diminished in size at 520 and 680 AGL. Over the next two passes (839 and 1000) the targets themselves appeared faint, and were occasionally lost. At the last pass (1160 AGL), the target was detected only on the southern part of the runway.

Date: 1-28-97 Time: 1105 LCL Rwy: 1L. Speed: 130 Kt Altitude: 200 AGL



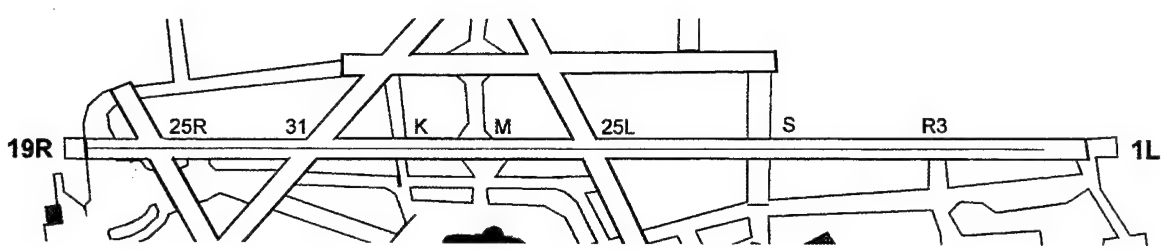
Comments: All target hits were normal. Unless a differential is noted on future passes, hits will be shown as a solid line.

Date: 1-28-97 Time: 1115 LCL Rwy: 19R. Speed: 130 Kt Altitude: 360 AGL



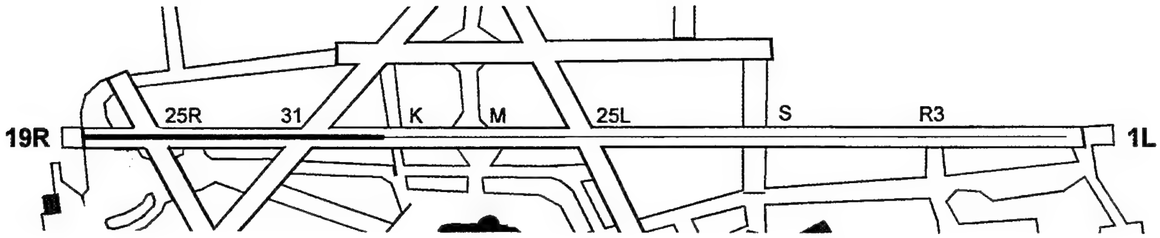
Comments: Normal targets full length.

Date: 1-28-97 Time: 1120 LCL Rwy: 19R. Speed: 130 Kt Altitude: 520 AGL



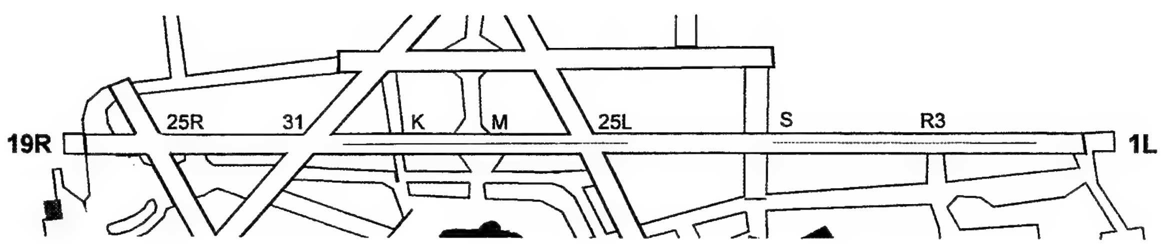
Comments: Targets were normal, but smaller. Had to turn mask off.

Date: 1-28-97   Time: 1127 LCL   Rwy: 19R.   Speed: 130 Kt   Altitude: 680 AGL



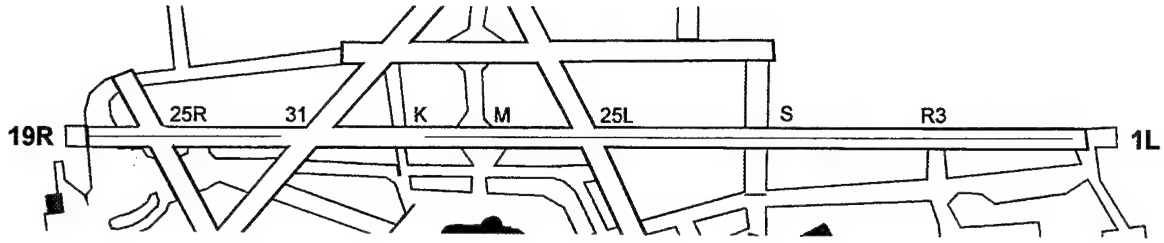
Comments: All target hits were normal, except area between [Rwys] M and K. Targets got a little stronger toward departure end of 19R.

Date: 1-28-97   Time: 1135 LCL   Rwy: 19R.   Speed: 130 Kt   Altitude: 839 AGL



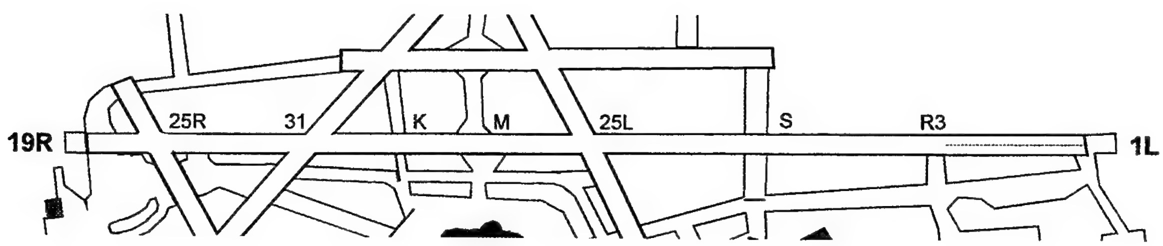
Comments: Intermittent weak targets. Lost track at S and again from Rwy 31 to departure end.

Date: 1-28-97 Time: 1140 LCL Rwy: 19R. Speed: 130 Kt Altitude: 1000 AGL



Comments: Normal but weak targets. Lost target between M and Rwy 31.

Date: 1-28-97 Time: 1146 LCL Rwy: 19R. Speed: 130 Kt Altitude: 1160 AGL



Comments: Had a couple of hits at the approach end, but lost target by R3. Never saw target after that.

4.2 TEST 2: DEMONSTRATION OF SHADOWING WITH DISSIMILAR SIZED TARGETS

This procedure identifies potential shadowing scenarios at various line-up points on the airport surface. Shadowing can obscure the registration of a target on the display. Radial lines extended from the tower on the accompanying surface map identify potential problem areas. A Phillip Morris HS25 Test Aircraft was used as the large aircraft and a C150 as the smaller target to test for shadowing problem areas on the airport surface. The test coordinator performed the procedure in conjunction with Ground Control.

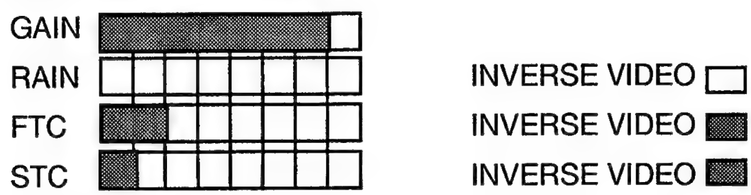
Procedure

The controller or test coordinator directed the two aircraft into potential shadowing positions on the airport surface, shown on the airport map (see Figure 4-4). The HS25 (large gray circle) was positioned in a radial line between the tower and the C150 (small gray circle).

Pretest Summary

Date: 1-27-97

Radar Settings [unchanged throughout test]:



Weather: [During tests 1a through 1d]:
[METAR:] 3/4 -SN VV009 [visibility ¾ mile, vertical visibility: indefinite ceiling of 900 ft.]
[RVR:] TD 4500 [at runway touchdown point, 4500 ft.]

During tests 2a through 4c:
[METAR:] 30010 KT 1¼ SM -SN BR OVC013 M05 / M07 A3005
[WNW wind at 10 knots, visibility 1.24 miles, light snow, mist, overcast 130 feet, temperature -5° C, dewpoint -7° C, altimeter [barometric pressure] 30.05]

Data Summary

In this test, the smaller, "shadowed" aircraft was a C 150 and the larger "shadowing" one the HS 25; the only exception was test 2a, where a target of opportunity replaced the HS25. At none of the fourteen tested runway positions was shadowing noted between the two aircraft. Most target descriptors written by the controllers were "normal," "good," and "distinct." Two initially "weak" targets were improved by increasing the GAIN; one "very weak" target may have resulted when the HS 25 itself may have been shadowed by a larger B 727 (Test 1c, see Figure 4-5). Test 4c (see Figure 4-6) shows typically normal (i.e., unshadowed) target returns of the two test aircraft at Runway 13.

The "shadowed" returns noted in 3b and 4a are not due to one aircraft shadowing another, but rather to a false target and a return from signage on the airport surface.

Test #	Small A/C	Return	Large A/C	Return	Comment
1a	C 150	Good	HS 25	Good	Targets normal, but weak; they improved with GAIN all the way up.
1b	C 150	Good	HS 25	Good	Normal–2 targets.
1c	C 150	Normal	HS 25	Very weak	HS 25 may have been shadowed by a B727 parked on ramp. **[see Fig 4-5]**
1d	C 150	Normal	HS 25	Normal	2 distinct targets.
2a	HS 25	Very solid, strong.	DC 9	Very solid, strong.	Both aircraft stopped in position. Both targets distinct, strong, readily discernible.
2b	C 150	Normal	HS 25	Normal	2 distinct targets.
2c	C 150	Normal	HS 25	Normal	2 distinct targets.
2d	C 150	Normal	HS 25	Normal	2 distinct targets.
3a	C 150	Normal	HS 25	Normal	2 distinct targets, till HS 25 was right behind C 150 [closer than normal.]
3b	C 150	Normal	HS 25	Shadowed	HS 25 not distinct. Ghost target on [Twy] K interfered with HS 25.
3c	C 150	Normal	HS 25	Normal	2 distinct targets.
4a	C 150	Normal	HS 25	Shadowed	Appears [that] we may be picking up signs [i.e., runway marker signs] which are shadowing the C 150.
4b	C 150	Normal	HS 25	Normal	2 distinct targets.
4c	C 150	Normal	HS 25	Normal	2 distinct targets. **[see Figure 4-6]**

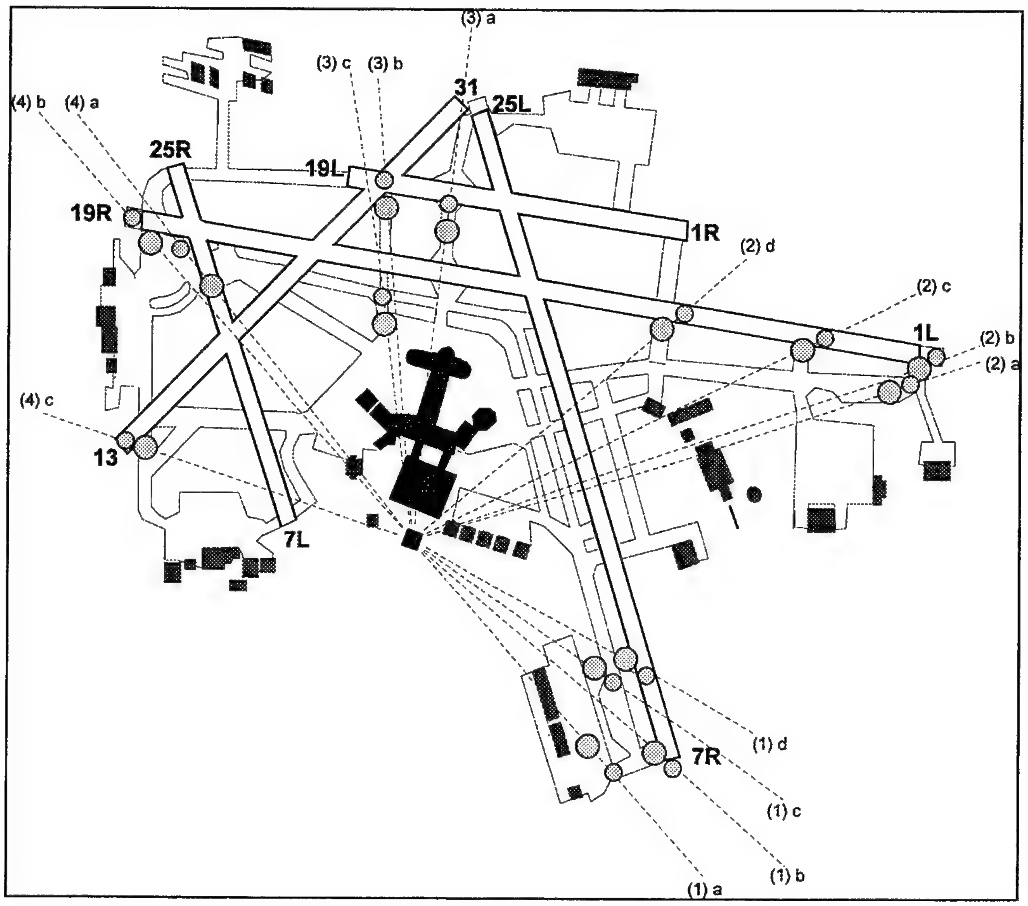


Figure 4-4. Shadowing Test Map.

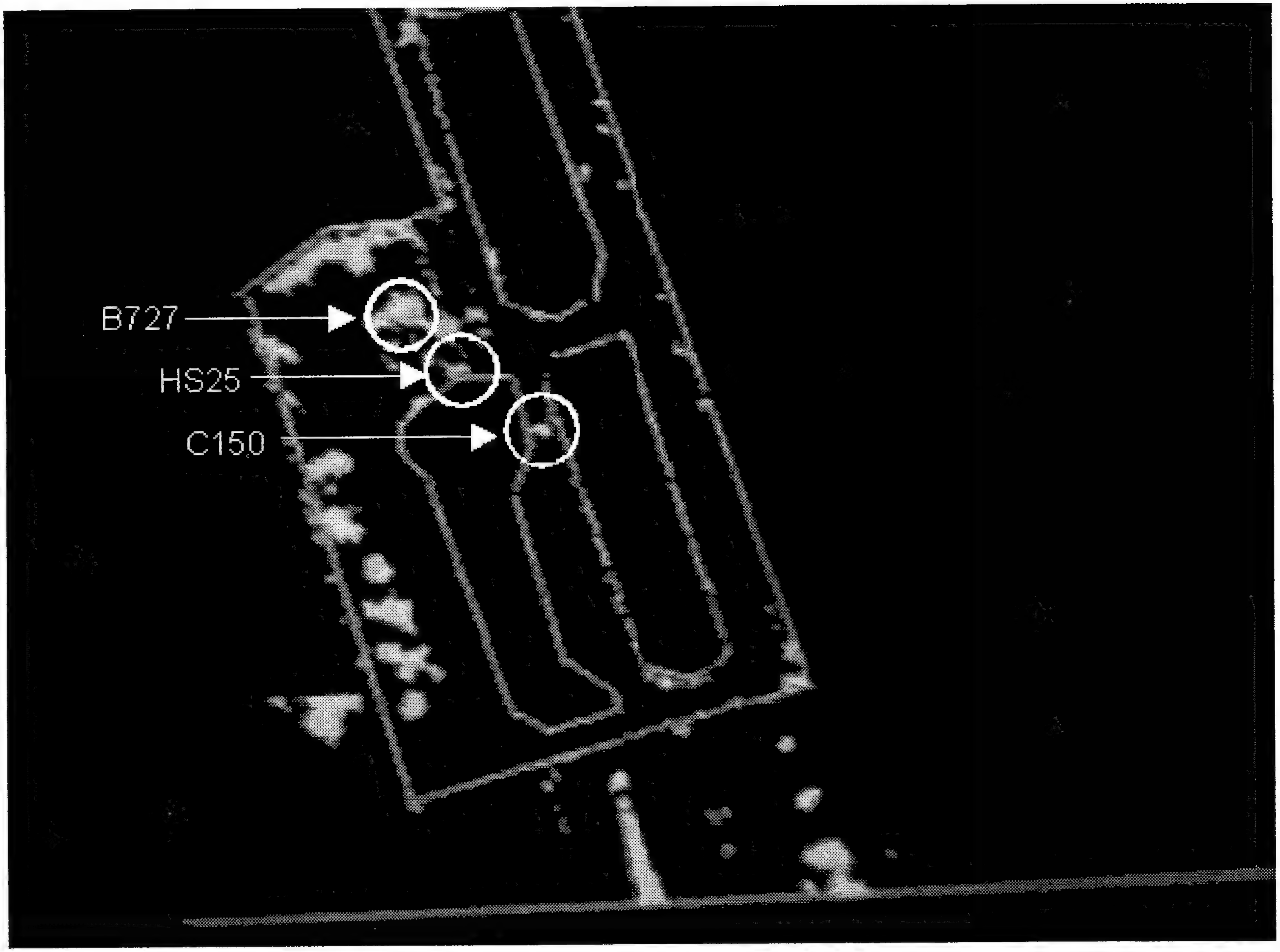


Figure 4-5. B727 Shadowing HS25 on Cargo Ramp.

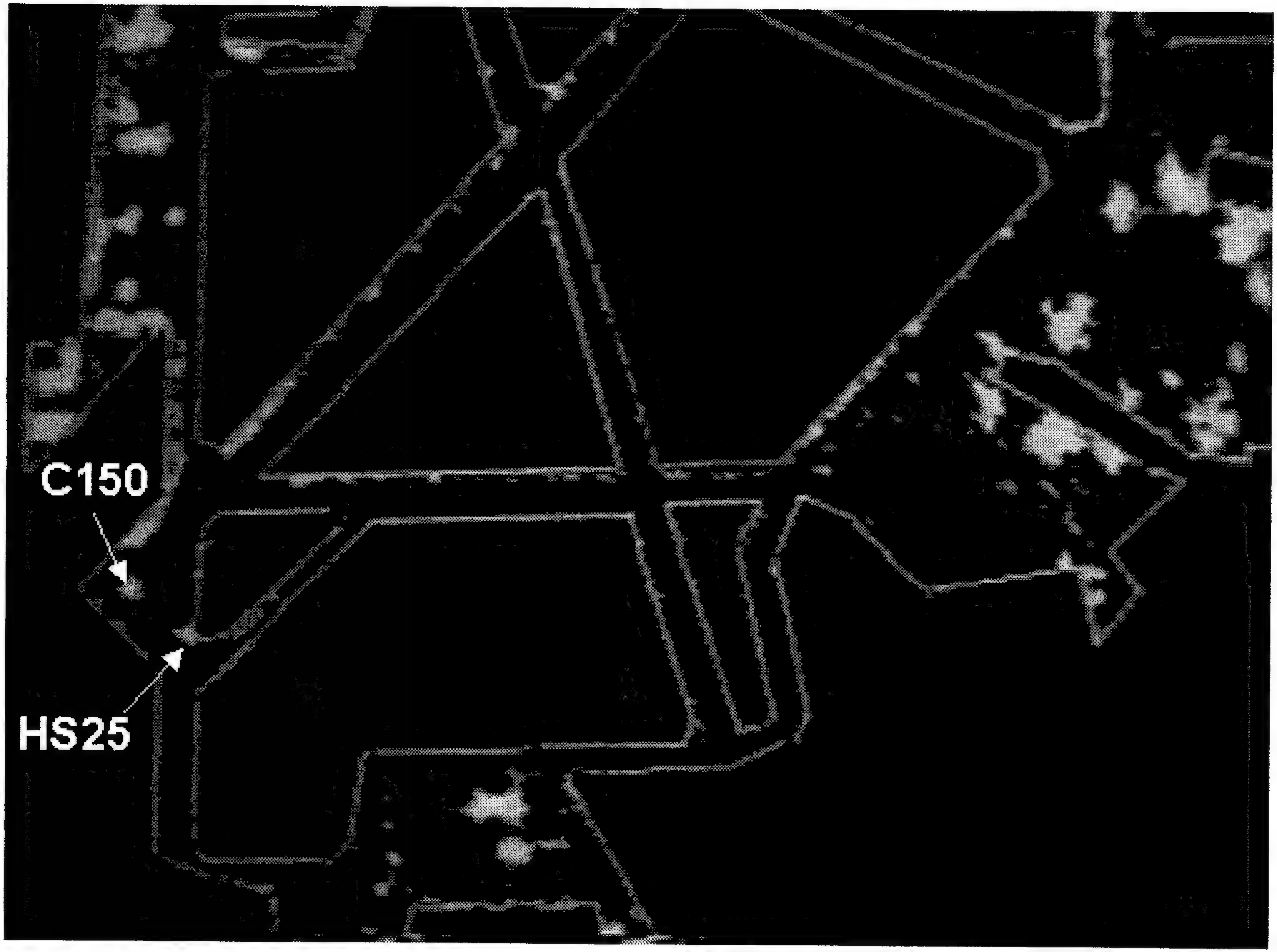


Figure 4-6. C150 and HS25 at Runway End 13, No Shadowing.

4.3 TEST 3: RADAR REGISTRATION OF TARGETS ON RUNWAY ENDS

This procedure demonstrates targets in position and hold at the runway end. The controllers tested the system monitoring various aircraft types (all targets of opportunity) moving into hold position on runway ends 31, 1L, 25L, and 19R. The test was run in Standard operating mode only, because MTI did not register targets that were stationary or moving slower than 70 kts.

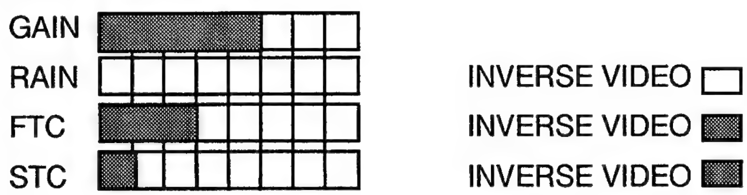
Procedure

Controllers were asked to view the display unit and monitor AT communications. They viewed the display to track aircraft to runway hold positions and recorded their observations. Then they looked away from the display for a minimum of three scans, relocated the target, and again recorded their observations.

Pretest Summary

Date: 1-27-97

Radar Settings:



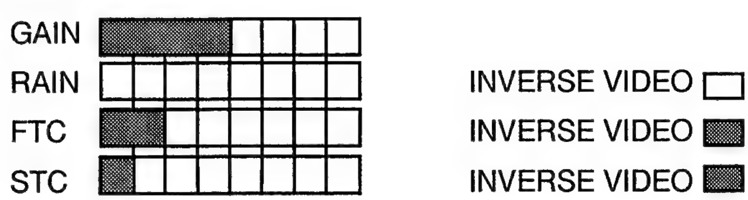
Weather: [METAR:] OVC 016 [overcast, visibility 1/16 mi.]

[RVR:] 6500 at runway touchdown, midpoint, and rollout.

NOTAM Surface Conditions on Rwy 25L: THIN LSR OVER PTCH THIN PSR 80 MN RDGS 33,34,35. [Thin loose snow on runway over patchy thin packed snow on runway, 80 feet either side of centerline has minor ridges.]

Date: 1-30-97

Radar Settings:



Weather: [METAR:] 9 SM CLR [9 miles tower visibility, clear]

Surface Conditions: Thin SIR (sheet ice on runway), sanded.

Data Summary

All 22 observations noted a good to very good return. Runway end observations included 25L (11), 19R (5), 31 (4), and 1L (2). Since the MTI functioned only at high speeds, all testing was done in Standard Mode. All targets noted were already in hold position. Times were noted in local time.

Rwy	Date	TimeLCL	A/CType	A/C ID	Comment
31	1/27	2026	BE40	NIHS	Good target
31	1/27	2046	BE58	USC431	Strong return; small target blends in with interference on North side of 31
31/1R	1/27	1837	C402	FRG555	Good target
31	1/27	1940	BE02	N521M	Good target
1L	1/27	2050	MD88	MEP975	Good target
1L	1/27	2016	DC9	MEP8350	Good target
25 L	1/27	1745	BE02	SYX1905	Good return
25 L	1/27	1743	E120	COM3195	Good return
25 L	1/27	1737	B757	1195	Good return
25 L	1/27	1733	BE02	SYX1204	Good return
25 L	1/27	1731	DC9	NWA951	Good return
25 L	1/27	1728	B737	COA1119	Good return
25 L	1/27	1725	DC9	MEP208	Good return
25 L	1/27	1720	B727	SCX953	Very good return
25 L	1/27	1703	HS25	N1KA	Very good return
25 L	1/27	1700	BE02	SYX1023	Very good return
25 L	1/27	1654	ATR72	EGF132	Looked great. Very bright target.
19 R	1/30	756	BE10	N36WH	Very distinct target
19 R	1/30	833	E120	—	Very distinct target, somewhat smaller than DC9 target.
19 R	1/30	831	DC9	MEP970	Very strong, distinct target.
19 R	1/30	830	BE02	SYX1162	Very distinct, strong target. In MTI, very, very faint target, barely discernible.
19 R	1/30	830	B737	—	Very large, strong target.

4.4 TEST 4: REGISTRATION OF NON-AIRCRAFT TARGETS IN TANDEM

This procedure tests the radar's effectiveness in registering non-aircraft targets traveling in tandem on the airport surface. Radar registration was tested with a pickup truck and a large snowblower, types normally used at MKE. The vehicles traveled singly or together, as in normal operations, over frequently used routes such as: the fire station to A1, the fire station to R to S. All tests were done in Standard Mode.

Procedure

Procedures were performed as indicated, with a single vehicle or with two vehicles in tandem, spaced from 10' to 100' apart. The test controller's instructions to the drivers of the vehicle(s) are noted in each of the lettered scenarios.

A. Snowblower solo:

1. Travel from the fire house to Rwy 1L via Twy S.
2. Wait for clearance to cross 1L.
3. Cross Rwy 1L and hold on Twy S.

B. Pickup truck solo:

1. Travel from the fire house to Rwy 1L via Twy S.
2. Wait for clearance to cross 1L.
3. Cross Rwy 1L and join the snowblower.

C. Pickup and Snowblower in tandem:

1. Travel in tandem to Firehouse Rd. via Twy S, R, and Y.

D. Pickup and Snowblower in tandem:

1. Travel in tandem from Firehouse Rd. to Rwy 7R via Twy A1.
2. Wait for clearance to cross 7R.
3. Cross Rwy in tandem 7R and continue along Twy A.

E: Targets of Opportunity:

1. Observed traveling East on Twy M.

Pretest Summary

Date: 1-28-97, 10:20 LCL

Data Summary

The airport surface was covered with snow at the time of testing; snowplows and sweepers were active. Controller observations of one to two typical airport vehicles (pickup and snowplow) traveling over two detailed airport routes showed consistently distinct targets down to a reported 15 feet of separation. Targets merged on the screen in one instance of 10' separation at Twy S, and became distinct again as

they were asked to increase the separation. Vehicles were observed from stationary (hold short) positions and traveling. All tests were done in Standard mode.

Sequence: A, B.
Location: L / Twy S.
Comment: Targets merged on S when 10' apart. Targets separated when 50' apart.

Figure 4-7, taken at sequence B3, shows the snowblower and pickup (center, circled). Targets are stationary, less than 50' apart, on Twy S, East of Rwy 1L. Note also the three snowplows traveling in tandem (lower left; two are merged), and the large aircraft (far right). The line along the East side of Rwy 1R is radar return from banked snow.

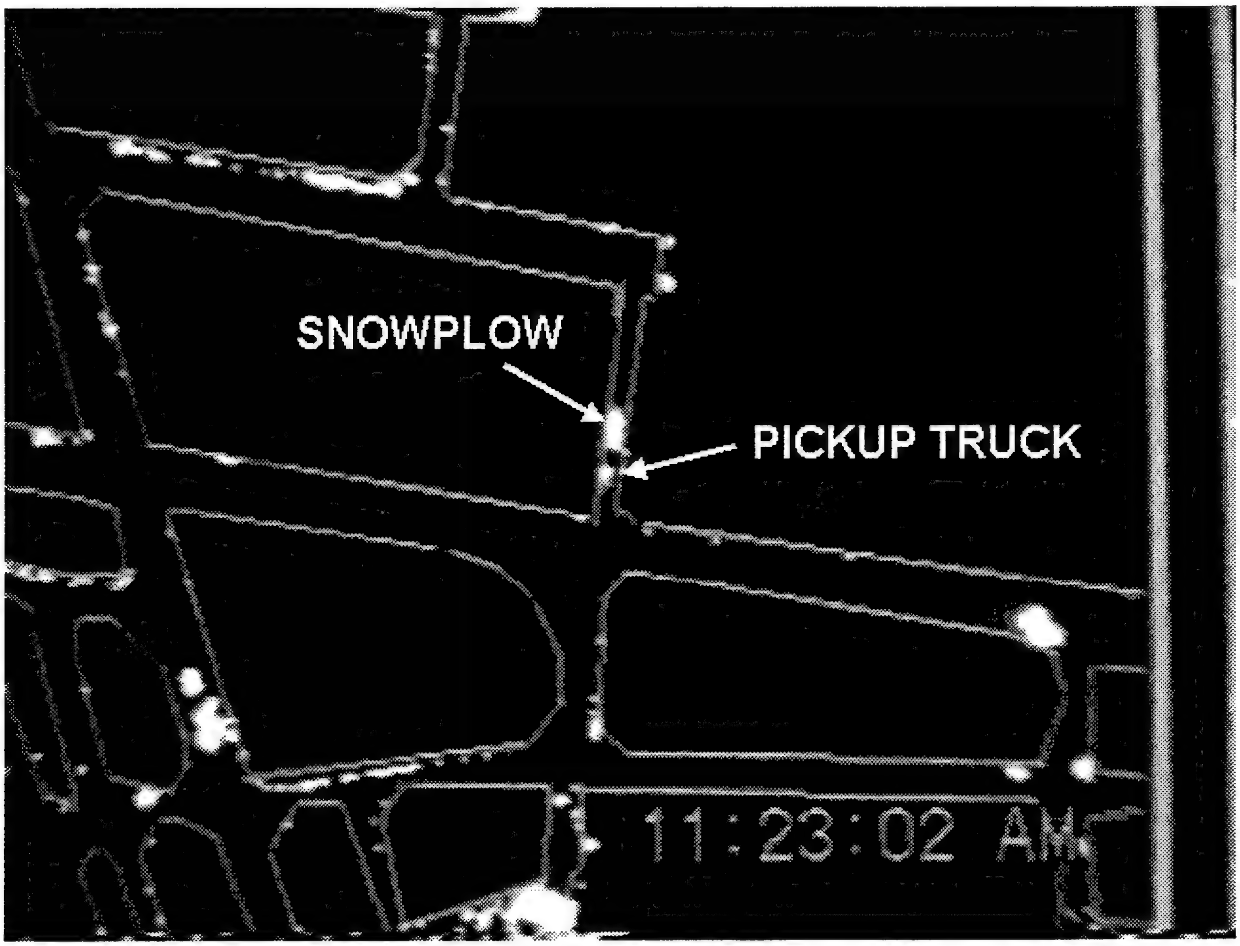


Figure 4-7. Pickup and Snowblower in Tandem, Stationary.

Sequence: C
Location: Firehouse Rd.
Comment: Had separation between targets at 15'.

Sequence: D
Location: 7 R / A 1. [A third vehicle joined the two test vehicles.]
Comment: Three vehicles crossing 7R at firehouse were distinctly separate.

Sequence: D.
Location: Southwest on Twy A [two test vehicles]
Comment: Separate at 75' apart.

Sequence: D.
Location: On A1, crossing 7R to Firehouse Rd.
Comment: Good target separation at 75'.

Sequence: D.
Location: Two rounding A to B at A2.
Comment: At 25' apart, had minimal target separation.

Sequence: E
Location: 1 L / Twy M
Comment: Three [targets] in tandem on M, (east of 1L), crossing 1L East to West. Separation between all three targets at 10-15'.

Figure 4-8 shows a sweeper (bottom) followed by two snowblowers (top) crossing Rwy 1L on Twy M.

Figure 4-8. Three Snow Removal Vehicles Traveling in Tandem.

4.5 TEST 5: HIGH-SPEED TURN-OFF DEMONSTRATION

This procedure demonstrated moving targets in transition from runway to taxiway. This test was run ten times with aircraft on Rwy 25L exiting onto A2, a critical high-speed taxiway exit (see Figure 4-9). The aircrafts' normal taxi and exit speeds were diminished by icy, slippery surface conditions.

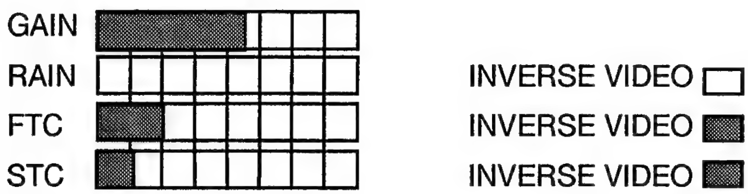
Procedure

Controllers observed targets of opportunity make approaches and high-speed exits onto Twy A2. Observers marked the data sheets at the point where the display registered the target after each update.

Pretest Summary

Date: 1-28-97

Radar Settings:



Weather: [METAR:] 27011KT 10SM CLR M19/M24 A 3047 [wind out of the west (270°) at 11 knots; visibility 10 miles, clear, temperature -19°C, dewpoint -24°C, altimeter [barometric pressure] 30.47.]

NOTAM remarks regarding surface conditions affecting R7R/25L: runway open, thin LSR over patchy thin PSR, 80' sanded [either side of the centerline], BRA-P by vehicle.

Date: 1-30-97

Weather: [METAR]: 27001KT 10SM SCT085 OVC150 A3007

NOTAM remarks regarding surface conditions affecting R7R/25L: patchy thin SIR.

Data Summary

Ten targets (mostly DC9, BE02 or BE03) registered consistent and normal on all turns off Rwy 25L onto Twy A2. No other routes were tested. Exit speeds, where noted, ranged from 25–50 knots.

Date	Target	Exit MPH	Exit Point	Comment
1/28	BE02	25	A2	Target uniform and consistent from rwy to twy.
1/28	BA31	--	A2	Target consistent and uniform on rwy and during transition.
1/30	BE02	15-20	A2	Normal.
1/30	DC9	--	A2	Target consistent and uniform from rwy to twy.
1/30	DC9	15-20	A2	Normal.
1/30	BE30	25	A2	Normal.
1/30	DC9	--	A2	Normal.
1/30	DC9	--	A2	Normal.
1/30	BE40	30	A2	Normal.
1/30	BA31	--	A2	Normal.

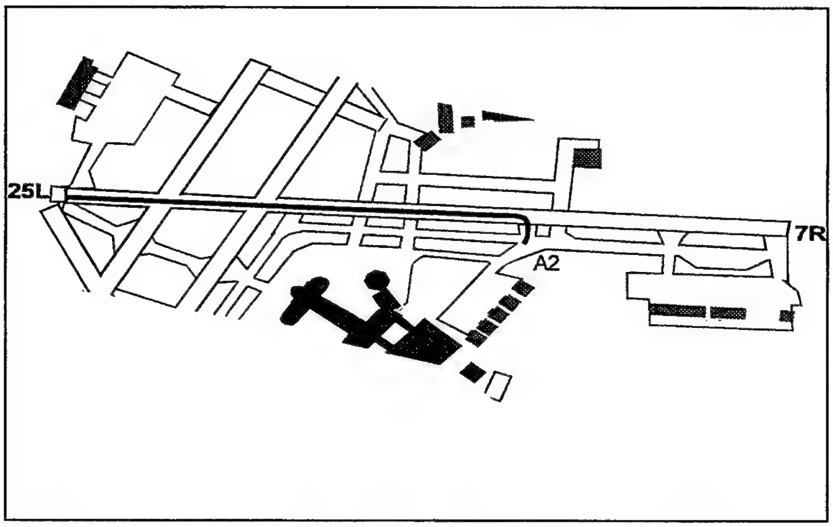


Figure 4-9. High-Speed Turn-off Test Route.

4.6 TEST 6: RADAR PRESENTATION AND DETECTION

This procedure tests the delay in presentation as an aircraft crosses the runway threshold on an approach. The procedure demonstrates system limits due to rates of antenna rotation and system update. The test measures time delta from when a target physically crosses the runway threshold and when it appears on the display.

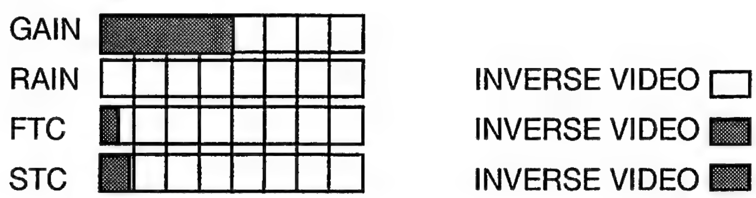
Procedure

Approach 25L was the focal point of this test, run ten times. A tower observer informs the team when a target of opportunity approaches the test runway. When the aircraft passes over the runway end, the field observer says "Mark" and then the tower observer starts the stopwatch. At the moment when the target appears on the display, a second tower observer says "Mark", the first tower observer stops the stopwatch and records the event.

Pretest Summary

Date: 1-27-97

Radar Settings:



Weather: [METAR:] 31008 KT 65M HZ OVC 007 M04/M07 A 3009 [wind out of the northwest (310°) at 8 knots, visibility 650 ft., haze, overcast w/ 700 ft. ceiling, temperature -4°C, dewpoint -7 altimeter [barometric pressure] 30.09.]

Data Summary

Ten targets were checked for the delay between their observed time of crossing the 25L threshold and the time they appeared on the display. An average delay of 1.16 seconds reflects the 60 rpm rotation speed of the antenna, plus the processing delay. Controllers made no written comments.

TEST	A/C TYPE	A/C ID	DELTA TIME
1	AT42	EGF043	1.25
2	BE02	SYX1022	1.28
3	B727	COA2073	1.26
4	BA31	CHQ442	1.28
5	LR23	KFS151	0.95
6	BE02	SYX1123	1.26
7	DC9	MEP151	0.86
8	BE02	SYX1055	1.36
9	BE02	SYX1091	0.93
10	WW24	N422BC	1.17

4.7 TEST 7: TARGET DISPLAY PRESENTATION

This procedure seeks controller feedback on target presentation in typical operations, using targets of opportunity. Controllers observed targets of opportunity and verified target characteristics (i.e., target split, break-up, fading, scattering, false targets, etc.) This test also gave controllers not otherwise involved in testing a chance to comment on radar operation. Because of the protracted target display testing, the results of two days are presented separately.

Procedure

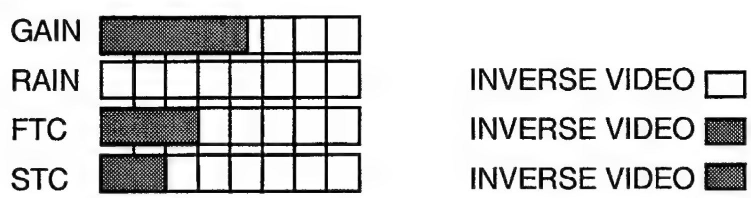
Controllers observed targets of opportunity at all airport locations and at various angles of presentation, and recorded target types and characteristics. A test form (see Figure 4-14 after Test 14) depicting the airport layout was provided for controllers' comments and included the following tracking instructions and descriptions:

A target should be tracked for the duration of its operation on the airport surface. Numerically mark events on the map and describe the event on the comment sheet. Potential events are:

Target Split:	Target splits into two or more targets, traveling in parallel.
Target Breakup:	Target breaks into several parts traveling on the same vector.
Target Fade:	Target loses intensity.

Pretest Summary, 1-27

Radar Settings [averaged]:



Weather: [METAR:] 27009 KT 7SM BKN011 OVC032 M04 / M07 A3007 [West wind at 9 knots, visibility 7 miles, broken clouds at 1100 feet, overcast at 3200 feet, temperature -4°C and dewpoint -7°C, altimeter (barometric pressure) 30.07]

NOTAM remarks regarding surface conditions affecting R7R/25L: runway open, thin LSR over patchy thin PSR, 80' sanded [either side of the centerline], MU readings 33/33/34 on 25L.

Data Summary, 1–27

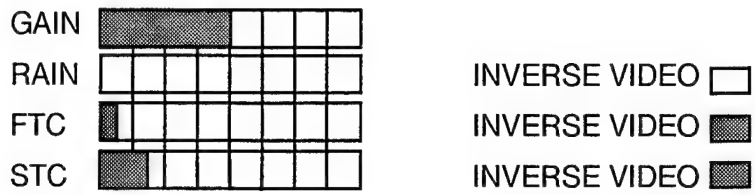
Of the 24 responses, about half in snow conditions (1/27) and half in clear (1/28), most targets appeared good, visible during observations. Image consistency was more of a problem, as controllers recorded 8 brief fades, 1 serious fade, 3 brief losses (proximate to tower), 6 slight break-ups, 3 brief splits. One BE10 was hard to pick up on Twy R in light snow.

KEY: P > B = taxiing from P to B; B (A2 > A1) = on B between A2 and A1; Y @ R = on Y at R; K ↲ E = turning off K onto E. **Terminals noted in boldface.**

A/C	AC ID	Taxi Path	Comments
BE10	N5727	P > B > A > R > 1 L	Target hard to pick up on P and B (A2 > A1). Return small, with fading and breakup on R (25L > 1L).
DC9	MCP114	**C** > B > R > 1L	Target normal except fade on B (E > R) and breakup on R @ 25L.
DC9	MEP114	Landed 1 L , taxied via K > **D**	Normal, except fade 1L ↲ K.
DC9	SYX1064	Landed 1 L , taxied via K > **D**	Normal, except fade 1L ↲ K.
BA46	AWI620	Landed 1L, taxied via M > E > A > R > Con D	Normal, except fade on E (M > 25 L).
DC9	MEP4	Landed 1L, taxied via M > E > K > Con D	Normal, except fade K ↲ M, and E ↲ K.
AT72	EGF231	Con C > K > E > A > R > 1L	Normal, except fade on E (K > M)
CL65	COM3837	Con C > B > R > 1L	Loss of target B ↲ R
BE02	SYX1163	Landed 1L, taxied > 25L > E > K > Con D	Loss for two sweeps R ↲ K
BE40	N272BC	F > 13 > G > B > R > 1L	Normal, except fade 13 ↲ G
BE90	N66TL	Landed 1 L, taxied > 25 L > E > F	Normal, except target fade and loss 1L ↲ 25L
DC9	MEP402	Con D > B > R > 1L	Normal, except target fade on B @ R, breakup and split (A @ R), and breakup (Y @ R)
DC9	NWA9711	B > R > 1L	Normal, except target breakup and fade on R @ Y, and breakup on R (S > R1).

Pretest Summary, 1-28

Radar Settings [averaged]:



Weather : [METAR:] CLR 10SM [clear, visibility ten statute miles]

NOTAM remarks regarding surface conditions affecting MKE Rwys.
R7R/25L: Rwy open, thin LSR over patchy thin PSR, 80' sanded [either side of the centerline], BRA-P by vehicle.
1L/19R: rwy open, 1L MU 39/39/39, patchy thin LSR over patchy thin SIR, 80' sanded, BRA-P by vehicle.

Data Summary, 1-28

KEY: P > B = taxiing from P to B; B (A2 > A1) = on B between A2 and A1; Y @ R = on Y at R; K ⅃ E = turning off K onto E. **Terminals noted in boldface.**

A/C	AC ID	Taxi Path	Comments
DC9	MCP4	A > E	Normal, except fades A (A1 > A2) and cornering A to E. **Note:** L1011 parked on South side of Concourse D.
DC9	MEP402	North side Con D > B > M	Normal, except target loss on B @ W side of Con D
DC9	MEP283	Landed 1L, taxied 31 > E > M > Con D	Normal, except fade 1L ⅃ 31, and on R (K > M).
BE02	SYX1049	K > B > M > 25L, closely trailing 2 DC9s on M	Normal, except serious fade on B (K > M)
BE02	N118SK	North side of Con D > B > C	Normal target presentation
DC9	MEP4	Con C > Con D > K > E > M > 25L	Strong target, except slight breakup K ⅃ E
AT42	EGR272	Landed 25 L, taxied A1 > A > E > M > B > West side of Con C	Normal, except slight breakup below **D**
BE58	--	F (13 > 19 R)	Brief split into three targets on F @ 13
DC10	AMT1834	R > A > E > M > 19R > K > B > Con E	Strong target whole route
DC9	--	A	Lost target on A (A1 > R)
NOPM	HS25	Landed 25L, taxied A3 > Y > R > R4	Normal, except brief fade Y ⅃ R, and breakup on R (S > R1).

4.8 TEST 8: FALSE TARGET DISPLAY PRESENTATION

This procedure had controllers observe occurrences of false targets. The controllers were informed of the probable causes and likely locations of false targets at MKE, and were asked to note radar settings and viewing conditions whenever false targets were observed. It was important that the test team record surface conditions and the locations of construction work, vehicles and aircraft on the airport surface. The movement area was arbitrarily divided into three regions, and about 30 minutes of observations were recorded within each region, with Region 2 being observed twice (see Figure 4-10). Radar settings were virtually identical on all observations.

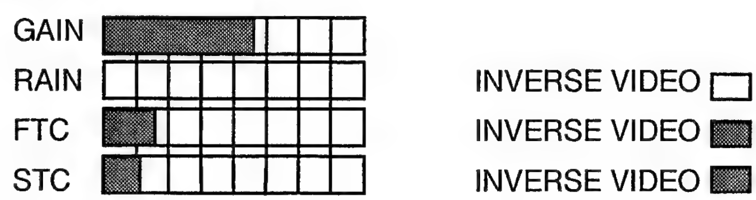
Procedure

The display was focused on one region at a time. With the video camera running, controllers noted false targets on the display, and verified them by sighting. Controllers curtailed the observations because map misalignments and the presence of snowbanks made accurate readings impossible.

Pretest Summary

Date: 1-28-97, 8–10 a.m.

Radar Settings:



Weather: [METAR:] CLR 10SM [clear, visibility ten statute miles]

NOTAM remarks regarding surface conditions affecting MKE Rwys.
R7R/25L: Rwy open, thin LSR over patchy thin PSR, 80' sanded [either side of the centerline], BRA-P by vehicle.
1L/19R: rwy open, 1L MU 39/39/39, patchy thin LSR over patchy thin SIR, 80' sanded, BRA-P by vehicle.

NOTE: The results of Tests 8 and 9 were adversely affected by the map registration. Some of the signs, lights, and other reflective surfaces positioned near runways and taxiways were displayed inside the mapped edges of taxiways and runways. Weather conditions also contributed to the difficulties, as some interference was attributed to snowbanks.

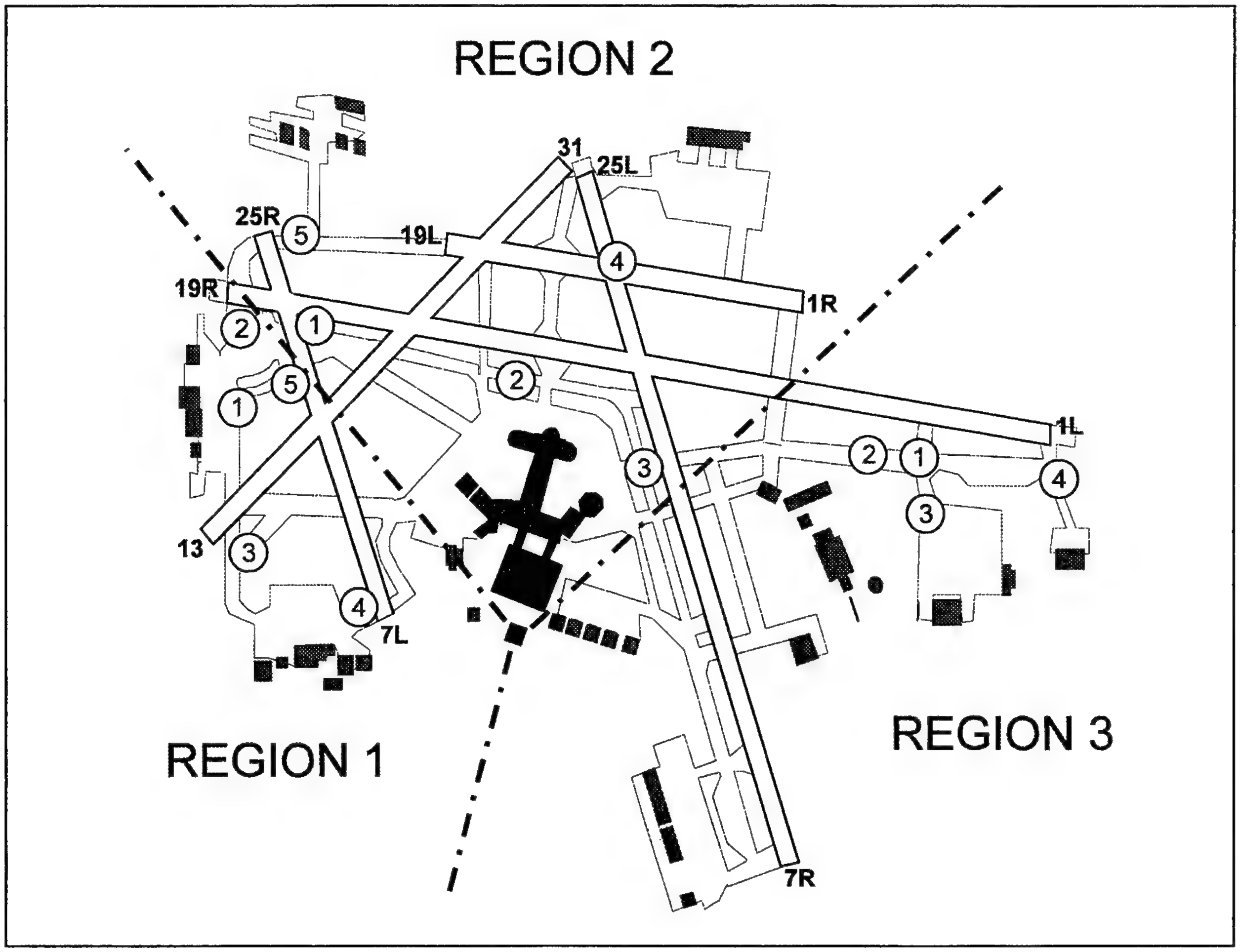


Figure 4-10. MKE Regional Map.

Data Summary

KEY: P > B = taxiing from P to B; B (A2 > A1) = on B between A2 and A1; Y @ R = on Y at R; K ┘ E = turning off K onto E. **Terminals noted in boldface.**

R – FT	False Target at:	False Target Type and Probable Cause
1-1	F 1	Possibly snow
1-2	E1 West of 19R app	Possibly a snowbank
1-3	F @ D1	Two FTs, small and intermittent
1-4	7L @ C	Possibly a sign
1-5	F @ 25 R	Intermittent FTs (1 long or 3 distinct and round)
2-1	19R > 25R Rwy ends	FT returns from multiple runway signs in this area
2-2	Twys K, M; E 19 R	Sign and/or snowbank
2-3	R @ A	Sign and/or snowbank
2-4	19 L @ 25 L	Sign and/or snowbank
2-5	Along H	Snow banked
3-1	R @ R 1	Permanent FT—sign reflection
3-2	N of R @ R 1	FT here disappears when true target is in the area.
3-3	R 3	Intermittent FT
3-4	R @ R 4	Permanent FT

False targets (FT) were innumerable (see note above). Figure 4-11 depicts the cluster of three FTs in Region 3 [1, 2, 3]; also note several large aircraft parked in the USAF Reserve lot (center), and one taking off from 1L (top center).

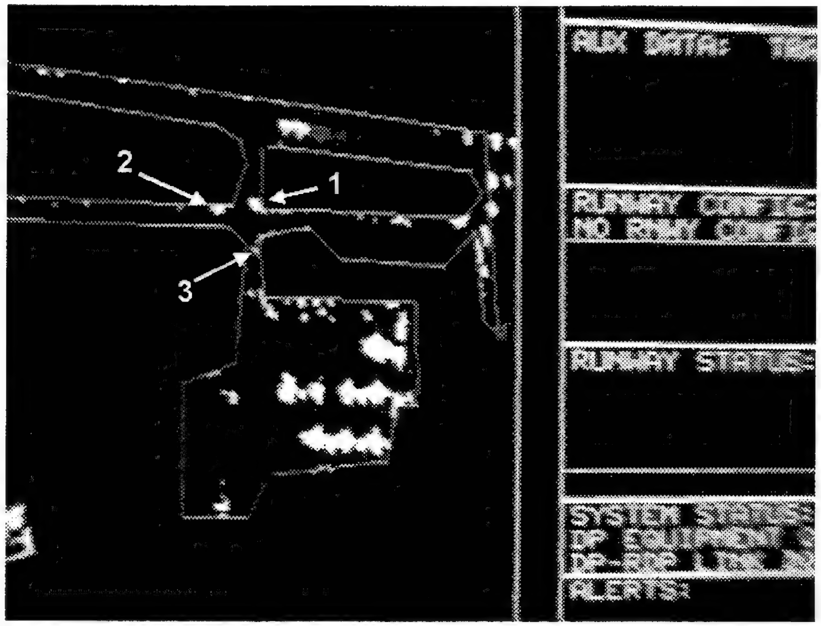


Figure 4-11. Three False Targets on Taxiway R.

Figure 4-12 shows FTs in Region 2 (1 and 2); moving aircraft (3, lower right); snowbanks along taxiway and runway edges and many aircraft and support vehicles around the terminals.

Figure 4-12. False Targets on Taxiways E and A.

4.9 TEST 9: POSITIONING ACCURACY TESTING

This procedure tests system ability to accurately represent target location by verifying that targets are displayed accurately in reference to the overlay map. The test covers all control movement areas at MKE. System limitations are verified in reference to the airport layout (runways, taxiways, ramps, terminals, etc.) Controllers identify vehicles, record location on a movement area map, and comment on their quality. The procedure also isolates problem areas associated with target registration. It was important that the test team record the airport's surface conditions, the location of construction work, and/or vehicles and aircraft on the airport surface. The movement area was arbitrarily divided into three regions, and thirty minutes of observations were recorded within each region, with Region 2 being tested twice.

Map registration was limited to the runway ends and sections of the critical movement areas. The validity of this test was limited due to poor map registration due to system failures and weather phenomena.

Procedure

The test team observed and recorded the test vehicle in all movement areas, including the center, right side and left side of each runway and taxiway, and all gate areas considered movement areas. The vehicle, for steps 1–7, was a full-sized Chevrolet Blazer, traveling at about 20 miles per hour. The test vehicle was switched to a Ford Bronco at the threshold of Rwy 7R (steps 8–39). The test team recorded each vehicle's movements and target quality, making special note of any target abnormalities. The test vehicles traveled the airport surface in the following sequence:

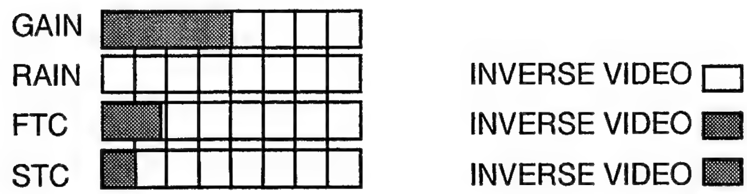
1. Parallel paths 50 feet apart, covering Terminal C to US Customs side of terminal area.
2. Parallel paths 50 feet apart back and forth between Terminals D and C.
3. Parallel paths 50 feet apart, back and forth between Terminals E and D.
4. Parallel paths on the South side of Terminal E.
5. Terminal E to Twy P via Twy B.
6. Twy A to Twy A4 to Cargo Ramp.
7. Cargo Area with parallel paths 50 feet apart.
8. Rwy 7R via Twy A5, traveling entire centerline of Rwy 7R.
9. Twy M to Twy E to Twy A.
10. Twy A toward Rwy end 7R stopping at Rwy hold points E, R, A1, A2, A3, A4 and A5.
11. Right side of Rwy 7R to Twy N, from Twy N to Twy W via Rwys 25L and 1R.
12. Twy W to the Fire Station via Twy S.
13. The Fire Station to the Citation Hangar.
14. The Citation Hangar to Twy A3 to Twy B.
15. Twy B to Twy Y via A1.
16. Twy Y to Twy B via Twy R.

17. Twy B to USAF Reserve via Twy R and Twy R3.
18. USAF Reserve with parallel paths 50 feet apart.
19. USAF Reserve to Phillip Morris via Twy R3 and Twy R4.
20. Entire centerline of Rwy 1L.
21. East hangars via Twys F, H and J.
22. Parallel paths 50 feet apart on East hangar area.
23. Rwy 19L via Twy H.
24. Rwy end 31 via Rwy 1R and Twy M.
25. Entire centerline of Rwy 31.
26. Skyway Maintenance area via Twys F and C.
27. Parallel paths 50 feet apart on Skyway Maintenance area.
28. Twy C to Rwy 7L.
29. Entire centerline of Rwy 7L.
30. Twy D via Twy F.
31. Twy D to Rwy 7L via Twy B.
32. D1 via Rwy 7L and Twy D.
33. Twy E via Twy F.
34. Twy E to Rwy 25L, stopping at Twy hold points E1 and E2.
35. Twy K via Rwys 25L and 31.
36. Twy G via Twy K.
37. Twy B via Twys G, E, F and D.
38. Twy B.

Pretest Summary

Date: 1-30-97

Radar Settings [at test start]:



Weather: [METAR]: 9 SM CLR M10 / M13
[visibility 9 miles, clear, temperature —10°C, dewpoint —13°C.]

Data Summary

Observations of the full-sized Blazer and Ford Explorer, following a detailed route to all corners of the airport surface, showed relatively good registration. The controllers noted numerous brief fades and some losses, mostly around the terminals (concourses), the Citation Hangar, and the Cargo Ramp. Problem areas are isolated from the routes on the data summary and bulleted on Figure 4-13.

> **NOTE:** The results of Tests 8 and 9 were adversely affected by the map registration. Some of the signs, lights, and other reflective surfaces positioned near runways and taxiways were displayed inside the mapped edges of taxiways and runways. Weather conditions also contributed to the difficulties, as some interference was attributed to snowbanks.

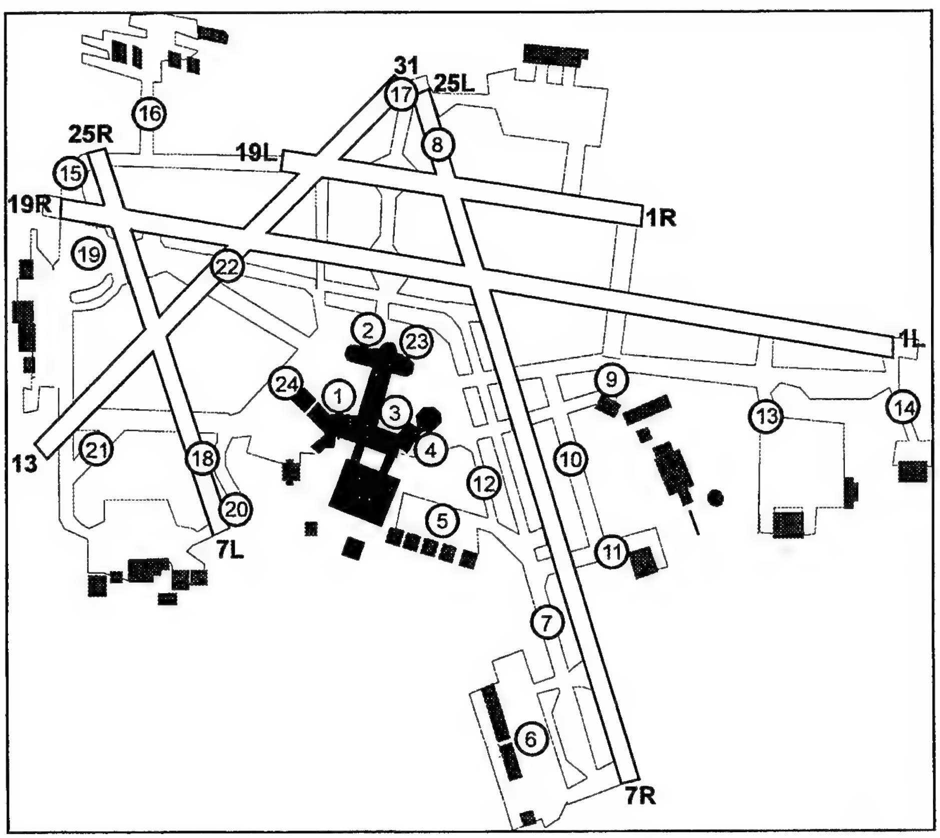


Figure 4-13. Position Accuracy Map.

Problem Areas

KEY: P > B = taxiing from P to B; B (A2 > A1) = on B between A2 and A1; Y @ R = on Y at R; K ↲ E = turning off K onto E. **Terminals are indicated in boldface.**

Bullet #	***Target Location***	***Comment***
1	**C** and **D**	Target was lost in clutter as it approached buildings. No return or visual contact. **NOTE:** radar settings were changed: GAIN 5, FTC 5 1/2, STC 1.
2	**D**	Lost target on B as it was circling **D**.
3	Between **D** and **E**	Whenever target was lost visually, it was also lost as a return.
4	SW side of **E**	Target lost in building and baggage car clutter.
5	B > P	Target lost on corporate ramp P in clutter, though target could be seen.
6	A > A4 > Cargo Ramp	Lost on Cargo Ramp, despite visual sighting. Target also shadowed on Ramp. **NOTE:** Vehicle changed to Ford Explorer, which yielded slightly better returns. Radar settings changed to GAIN 7, FTC 5, STC 1.
7	M > E > A	Weak target on A (A3 > A4). Lost on 7R.
8	7R (1R > N)	Weak target.
9	Firehouse ramps	Target losses intermittent.
10	Y	Weak.
11	Citation Ramp	Extremely weak.
12	Twy B (A3 > R)	Extremely weak.
13	R @ R3	Lost.
14	Phillip Morris Ramp	No target until mask was turned off.
15	H (F > 25R)	Lost.
16	East Ramp	No target.
17	M ↲ 31	Target lost.
18	7L > D	Weak.
19	E	Target blends with signage return.
20	B ↲ 7L	Loss.
21	D1	Weak.
22	31 (E > 1L)	Targets break up.
23	B (south of M)	Lost.
24	**C**	Lost.

4.10 TEST 10: SURVEILLANCE UPDATE RATE

This procedure tests the radar display update rate by timing radar sweeps.

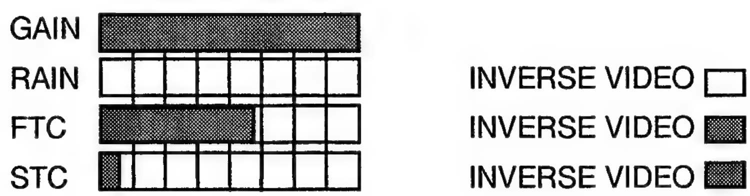
Procedure

1. Focus on the fixed target. Start stopwatch.
2. Count 100 sweeps.
3. Stop stopwatch when 100 sweeps have been counted. Record time.
4. Repeat steps 1 - 3 ten times.

Pretest Summary

Date: 1-27-97

Radar Settings:



Weather: [METAR:] 29008 KT 5SM BR SCT007 OVC 016 M04 / M06 A3011

[Wind WNW (290°) at 8 knots; visibility 5 mi.; mist; scattered clouds at 700 foot ceiling; overcast 1600 feet, temperature -4°C, dewpoint -6°C; altimeter [barometric pressure] 30.11.]

Data Summary

The antenna update rate was timed at .99 second per rotation, or approximately 1 rotation per second.

KEY: Time = time delta per 100 radar sweeps, in seconds.
Tests 9 and 10 were run in MTI mode.

TEST	1	2	3	4	5	6	7	8	9	10
TIME	99.24	90.05	99.52	100.3 1	99.31	100.31	100.27	100.29	100.38	100.46

4.11 TEST 11: PROBABILITY OF DETECTION

To be accepted by the FAA, an ASDE radar system should meet the ASDE-3 requirement to provide surface detection coverage with a minimum probability factor of 90% during a single scan of a target with a detectable surface of $3m^2$ (i.e., FTRs T1 and T2). Ten tests counted radar 'hits' (detections) of the FTR. All tests were run in Standard Mode; targets did not register in MTI Mode.

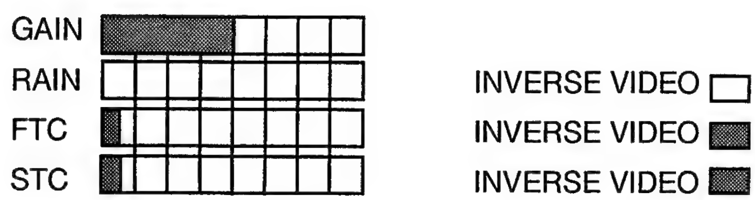
Procedure

One of the $3m^2$ FTRs was located on the display and observed for 100 scans of the radar. The number of scans in which the FTR was detected were recorded.

Pretest Summary

Date: 1-27-97

Radar Settings:



Weather: [METAR:] 29008 KT 5SM BR SCT007 OVC 016 M04 / M06 A3011
[Wind WNW (290°) at 8 knots; visibility 5 mi.; mist; scattered clouds at 700 foot ceiling; overcast 1600 feet, temperature -4°C, dewpoint -6°C; altimeter [barometric pressure] 30.11.]

Data Summary

The radar surpassed the specification probability of detection accuracy of 90%, as on ten tests of 100 sweeps each, the radar detected the $3m^2$ FTR an average of 98.3 times. All tests were done in Standard Mode.

KEY: HITS = FTR detections in 100 sweeps.

TEST	1	2	3	4	5	6	7	8	9	10	**AVG**
HITS	**100**	**94**	**99**	**100**	**100**	**100**	**99**	**98**	**94**	**99**	**98.3**

4.12 TEST 12: DISPLAY SATISFACTION TESTING

This procedure solicited controller commentary on the radar system's display, controls, and functions. Controllers were encouraged to suggest enhancements and improvements to the radar's display that would, from their perspective, facilitate ATC operations.

Procedure

NOTE: This test covers the general operation of the display unit. Controllers should operate the unit and independently record their views on system operation and suggestions for system enhancements or improvements.

1. Adjust sensitivity controls according to notes provided below. Tune the system to the FTRs at the end of Rwy 1L across College Road. Comment on both the individual sensitivity controls and on the controls as a whole.

NOTE: Adjust GAIN for light background speckle (dim level). A gain bar graph in the lower right corner of the screen indicates the setting of gain control. Once set, GAIN will be maintained at all ranges. GAIN should be readjusted as conditions change (rain).

2. Record GAIN setting, sensitivity of adjustment and your comments.

NOTE: Adjust STC control for even clutter suppression. The ideal setting reduces moving grass returns to a light speckle. Adjust in small increments; pause to observe three scans for results.
In heavy grass clutter peaks may come through at brighter levels, so average settings work best.

3. Record STC setting, sensitivity of adjustment and your comments.

NOTE: Adjust RAIN and FTC controls as needed. These enable suppression of radar returns resulting from radar signals reflected from rain drops (rain clutter). Advance RAIN slightly and observe the results (three scans). The idea is to push nearby rain clutter down to a very light speckle at the dim level. FTC filters or differentiates rain clutter; restoring weaker targets lost due to RAIN adjustment, reducing land echoes, and thinning out larger targets. The RAIN and FTC indicators appear to the right of the screen.

4 Record RAIN, settings, sensitivity of adjustment, your comments.

5. Record FTC, settings, sensitivity of adjustment, your comments.

6. Comment on the tuning and overall adjustment of the sensitivity controls.

7. Operate the system at various range levels. Comment at each level on target presentation, situation awareness, map presentation and general usefulness. Include preferred operating range versus airport configuration and/or operating conditions.

NOTE: The DATA BRILL switch varies the intensity of all data *outside* the radar display area. Perform testing at all three settings (dim, mid, or bright.

8. Set the system on each level of Data Brilliance. Comment on feature's usefulness; include your preferred operating mode for day and for night.

NOTE: Pressing MTI causes fast moving targets to appear brighter. When this function is active, clutter and stationary targets appear dim on the display.

9. Most tests will be performed in Standard and MTI modes. Please comment on Standard mode of operation; indicate your preference, both in general and in specific ATC operations.

10. Please comment on MTI mode of operation; indicate your preference, both in general and in specific ATC operations.

NOTE: The Offset button enables the tower to be offset up to 70% in any direction. This function increases the field of view of runway ends without the use of longer range settings. When offset is selected, the radar display area will blank and rebuild in three revolutions of the antenna.

11. Comment on the usefulness of Offset in all the settings. List various useful operations for Offset, and any safety issues that may occur.

NOTE: The MAP LINES push button in the cursor group allows the operator to establish up to 1000 true points or up to 999 contiguous lines (Rwy - Twy map). These marks may be placed on selected points when in North-Up or View-Up operation. Once entered into the system, lines are treated as stationary objects by being true motion stabilized and fixed to the radar map. A line's length and position are changed to reflect any changes in range scale, and display offsets.

12. Use the MAP LINES feature to create a runway/taxiway map. Comment on the map building process and suggest enhancements. Comment on how multiple maps can be used to enhance AT operations.

13. Use Map Rotation (North Up / View Up) to rotate map. Comment.

14. Comment on Masking capabilities (create, edit, emergency turn-off.)

15. Comment on Electronic Line Bearing (ELB).

16. Comment on Cursor Mark.

17. Comment on Auxiliary Line.

18. Comment on Site Map BRILL.

Data Summary

Four controllers commented on their views of system functionality on the above questionnaire, and their responses are summarized below. They had been trained on system operation and were an integral part of these tests and observations.

Q#	TOPIC	COMMENTS
1	**FTR Focus**	Often hard to pick out FTRs from surrounding clutter.
2	**GAIN Setting**	Satisfactory: easy to use, fine tuning impacts quality of returns.
3	**STC Setting**	Effective, successfully balances return intensity.
4	**RAIN Setting**	Not used (no bad Wx).
5	**FTC Setting**	Over-sensitive, requires excessive tuning, but does reduce clutter.
6	**Overall Adjustment**	Effective: clean presentation; strong targets.
7	**Range Operation**	Requests for finer increment selections, especially between 0 and 3 nm.
8	**Data Brilliance**	Hard to adjust; low brilliance difficult to discern under certain lighting conditions.
9	**Standard Mode**	Good.
10	**MTI Mode**	Useless: does not pick up taxiing or stationary vehicles on airport surface.
11	**Offset**	Limited: return-to-center needed; presets only applicable in set range.
12	**Map Building**	Ineffective: tedious to make, hard to modify, impossible to save more than two.
13	**Rotation(North/ViewUp)**	Flexible, but NorthUp maps not in sync with radar; needs more options.
14	**Masking**	Good, but needs to cover more clutter.
15	**ELB**	OK, not much use.
16	**Cursor Mark**	OK, not much use.
17	**Aux(iliary) Line**	OK, not much use.
18	**Site Map BRILL(iance)**	Hard to adjust. Low brilliance is too low.

4.13 TEST 13: SYSTEM SATISFACTION ASSESSMENT QUESTIONNAIRE

A questionnaire asked controllers to assess the general utility of the radar system for AT operations. In evaluating the system's operator interface they answered (with examples) questions, summarized generally with these concepts:

- Are messages easy to understand?
- Are controls easy to use?
- Does the system give you a "complete picture" of surface awareness?
- Does the system respond quickly and accurately to your commands?
- Do you see all information you need on the display?
- Is it easy for you to keep track of your actions and status?
- Are alerts clear in meaning and prominently displayed?
- Do you know how to respond to them?

Controllers were first asked to evaluate the training session itself, using a scale of 1-5[1] to rate: coverage of operations, verbal presentation, user manual completeness and organization, and their confidence factor that the training prepared them for using the radar system effectively. Ratings ranged from 4 to 5 in all categories. When asked whether any radar topics remained uncovered or were unclear, controllers offered no suggestions for training improvements.

Areas of questions on the radar system interface included: Auditory Alerts, Data Entry Devices, Display Screens and Controls, Ergonomics and Workload, Functional Capabilities, and Summary Questions. The questionnaire is attached as Appendix C.

[1] The ascending ratings categories were unsatisfactory, fair, good, very good, excellent.

Data Summary

The four controllers filled out their questionnaires in these categories. Their answers are summarized below and are examined in detail in Section 5.2

QUESTION	RATING	COMMENTS
Was Data Entry Easy?	Sometimes	Touch pad hypersensitivity causes accidental changes.
Menus, Displays Clear?	Always	[No comments.]
Trackball Easy to Use?	Sometimes	Trackball can be awkward to use.
Touch Pad Easy to Use?	Sometimes	Needs rheostat to control excessive brightness.
Mapping Capability Problems?	Always	Labor-intensive to create, simple modification impossible, no protection from deletion. Map scanning capability would be useful.
Controls Well Positioned?	Sometimes	Trackball and unlocking device of display arm are badly positioned.
Control Sequence in Logical Order?	Always	[No comment]
Labels & Boxes Well-Positioned?	Sometimes	Eliminate unused "boxes", move data (EBL, radar, etc.) to touch pad to allow full-screen airport map.
Labels & Commands Clear?	Always	Clear and simple.
Text Easy to Read?	Always	[No comment]
Screens Well Laid Out?	Sometimes	User setup option needed.
Monitor Readable In All Light?	Always	When adjusted, yes.
All Airport Views Attainable?	Always	Range increments between .1 and 1.5 nm requested.
System Response Fast?	Sometimes	Response after 3 sweeps OK. Touch pad may ignore or repeat entries.
Vital Data Missing?	Sometimes	Validated maps; alert systems needed for: radar degradation, component failure, or antenna slowdown.
Control Mods for Efficiency?	NA	Place touch pad and trackball in closer proximity. Move control boxes into more efficient configuration. Full screen display of map.
Error Message Response?	NA	[None available.]
Does system Enhance / Impede AT Operations?	Enhance	"No doubt about it!"

4.14 TEST 14: LOW VISIBILITY PRESENTATION TEST

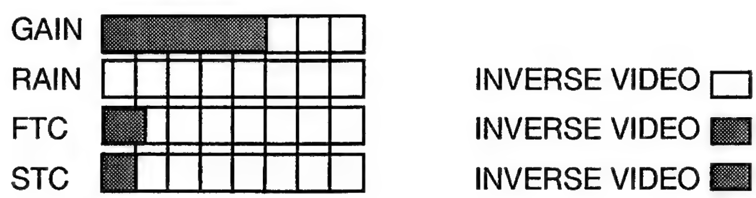
This test aimed to gather information for use in developing operational procedures for ASDE radar systems during low visibility operations. Controllers on duty were asked to fill out data forms (see Figure 4-14) left in the ATCT cab expressly during adverse weather (especially rain). They were asked to identify system characteristics and performance, and to document any adjustments made to the system's controls to reduce clutter due to the precipitation. They were also asked to state their impressions of the radar's usefulness, and to suggest system enhancements that may well affect future surface radar design. Low visibility data was collected on an ad hoc basis between February and April. The test form reviews the main target anomaly types to be noted (split, breakup, and fade).

Procedure

Controllers were asked to fill out forms during low visibility (especially rain) conditions. Instructions on the pretest form (not shown) were to mark the map with circled numbers in each location where a target fades, splits, breaks up, or is lost; and to note areas of recurring target abnormalities (fades, splits, breakups) and add comments referenced to each circled number.

Pretest Summary

Radar Settings [average]:



Operational Assessment of Raytheon ASDE Radar

Located at General Mitchell International Airport

TEST 14: LOW VISIBILITY PRESENTATION TEST

Procedure:

The information obtained from this test will be used to develop operational procedures for ASDE radar systems during low visibility operations. It is important to identify the strengths and weaknesses of the system and to capture the controllers' general impressions. The controllers' suggestions for enhancements to the system will affect the configuration of future Low Cost ASDE systems.

Please be sure to capture data during rainfall. Rain has the most adverse effect on the radar. Controllers should take special note to document any adjustments made to the systems controls to reduce clutter due to the precipitation.

Date: ______________ Time: ______________

Test Team: Observer: ________________________________

Aircraft/Vehicle: Model: ______________ Make: ____________

Radar Information:

Radar Settings:

TUNE ☐☐☐☐☐☐☐☐

GAIN ☐☐☐☐☐☐☐☐

RAIN ☐☐☐☐☐☐☐☐ INVERSE VIDEO ☐

FTC ☐☐☐☐☐☐☐☐ INVERSE VIDEO ☐

STC ☐☐☐☐☐☐☐☐ INVERSE VIDEO ☐

FAST TARGETS ☐ STANDARD ☐

PULSE WIDTH: .04μsec RANGE SETTING __________

Weather:

METAR: ____

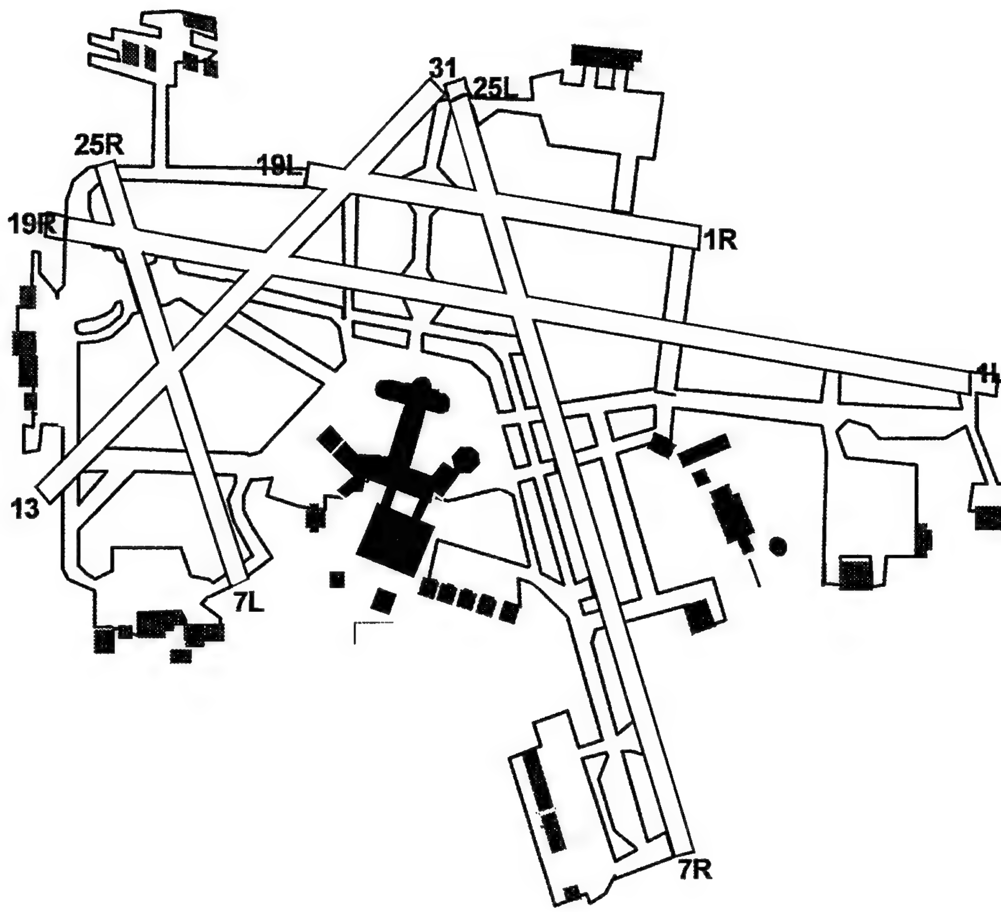
RVR: TD____________MID___________ROLLOUT____________

Visibility (Operator)____________________________________

Figure 4-14a. Low Visibility Test Form, Front.

A target should be tracked for the duration of its operation on the airport surface. Numerically mark events on the map and describe the event on the comment sheet. Potential events include:

- Target Split - target splits into two or more targets, traveling in parallel.
- Target Breakup - Target breaks into several parts traveling on same vector.
- Target Fade - Target loses intensity.



Comments: ____

____

____

____

____

Figure 4-14b. Low Visibility Test Form, Reverse.

Data Summary

The low visibility test results were twelve forms filled in by controllers on two days (February 7 and April 11) with snow, rain, freezing fog and mist and several (May 17 through July 8) with thunderstorms and fog. The data sheet summaries below explain the METAR weather code, identify the target aircraft type, indicate the airport surface area covered, and give the comment of the observing controller.

KEY: P > B = taxiing from P to B; B (A2 > A1) = on B between A2 and A1; Y @ R = on Y at R; K ┘ E = turning off K onto E. **Terminals designated in boldface.**

Weather [uncoded METAR]	*Target*	*Area Covered*	*Comment*
light rain, mist, overcast, 400 ft.	DC9	**D** > A > 7R Pad	Good target entire distance. Snowplows & other vehicles also looked good.
light snow, mist, overcast, 400 ft.	BA31	7R Pad > A > **D**	R: Brief Loss, between R & E: Lost several sweeps, M > B: Lost on turn M > B.
light snow, rain, overcast, 200 ft.	DC9	7R > E > A > R	Good target all the way.
light snow, rain, overcast, 200 ft.	BA46	**D** > R > A > 7R	Good target all the way.
¼ mi. vis., mist, overcast, 200 ft.	BE02	7R > E > K > **D**	OK, always visible despite fade (R > E).
½ mi. vis., (vertical 900 ft.), mist, snow	C650	7R > E > A2 > P	Small, weak target all the way; three spot fades, esp. at E & A.
½ mi. vis., snow, freezing fog, overcast 400ft.	ATR72	**C** > B > A > 7R Pad	**C, D:** fade & breakup; **E**: fade; A3-A5: reduced in size and intensity.
½ mi. vis., snow, freezing fog, overcast 400ft.	E120	**C** > E > A > 7R Pad	Customs: fade and disappear; shadowing at A & E.
½ mi. vis., snow, freezing fog, overcast 400ft.	1van,2 trucks	½ 19R, ½ 31/13, all 7R/25L	All three targets distinguishable on 7R @ A3; smallest (Explorer) always intermittent; larger two merge on 25L (R > rwy end).
½ mi. vis., snow, freezing fog, overcast 400ft.	—	A (R > A1)	Much clutter after slight (.125") snow.
½ mi. vis., snow, freezing fog, overcast 400ft.	C560	K > Rwy end 19R	Target faded on 19R between K and Rwy 25R.
¾ mi. vis., lt snow, mist, overcast 200 ft.	DC9	**D** > A > R	Good target full route.
< ½ mi. vis., thunderstorm, rain	--	[general remarks]	Difficult to get targets every sweep during heavy rain. After rain, good presentation w/ same settings.
¾ mi. vis., mist, overcast 100 ft.	DC8	1L > R	Target weak R (S > R3), elsewhere very strong.
1¾ mi. vis., fog	ATR72	---	Very nice presentation.
1 mi. vis., fog	3 tractors	crossing 7R @ A1	Great, distinct presentation.
¼ mi. vis. (vertical 100 ft.), drizzle, fog	BE02, C402, DC9	B	Targets good, except extremely weak K > R.
¼ mi. vis. (vertical 100 ft.), drizzle, fog	CL61, BE02	E (K > R > B)	Targets weak.
½ mi. vis., thunderstorm, rain, broken clouds at 900 ft.	--	[general remarks]	Targets not visible with RAIN off, at 50% showed best targets all quads, except weak South of S.

5. ANALYSIS AND RECOMMENDATIONS

Raytheon's ASDE radar (M 3625 / 19 CPX-12)--as tested in MKE's Phase II--has been found to be a viable surface surveillance system, and a potential FAA low cost ASDE solution for smaller airports. The low-cost COTS radar shows promise as a controllers' aid in monitoring surface traffic of non-cooperative targets. The following summarizes the system's performance at MKE, compares functional test data and specifications to ASDE-3, and analyzes the operators' assessment of the system's utility in the ATC environment. It takes into account various performance shortcomings and hardware failures encountered during installation and testing.

5.1 SYSTEM INSTALLATION AND ANALYSIS

The initial configuration meeting involving the purchase of a low-cost ASDE system to be tested in MKE took place in the fall of 1995 at Raytheon Marine in Manchester, NH. The FAA's intentions were to test the Raytheon ASDE product installed in Bombay International Airport. With cost in mind, the FAA requested the Milwaukee system be non-redundant and the India's system tracker and collision avoidance reporting capability be removed. The elimination of these features led to a Milwaukee configuration (Figures 1-1, 2-2) with an equipment and onsite training cost of $249K. The elimination of the above features necessitated a re-engineering of the India ASDE by Raytheon Marine. A non-recurring engineering cost of $71K was earmarked for Raytheon to develop a mapbuilding utility to replace the functionality lost with the tracker/safety logic processing. The money also covered system adaptation for operation without the India ASDE Performance Monitoring Unit (PMU), which controlled switching of redundant components.

These changes had direct bearing on two major system shortcomings reported by the controllers. The map overlay utility delivered with the system made building and editing accurate airport overlays very difficult. Raytheon is updating this utility to include many of the controllers improvement suggestions. A firmware update is scheduled for July 1997. The system's lack of Built In Test (BIT) reporting--related to the elimination of the PMU--also drew complaints. BIT reporting capability will be a requirement for any operational ASDE system.

The Raytheon MKE ASDE provided high-resolution, ground-surveillance radar which presents controllers with a screen display of stationary and moving aircraft and vehicles. It is designed with standardized, modular, easily replaced components which require a short mean time to repair. The system was purchased with a 1-year service and parts warranty and a set of high-priority spares (see Appendix E).

The radar's options / capabilities enable it to serve as a sensor for the detection, surveillance, and control of surface vehicles in configurations where the visual line-of-sight is limited and in low visibility weather conditions. The radar's range and azimuth resolution allow it to produce well-defined images at ranges out to 1 1/2 nm. The pulse-type system comprises a 25 kW X-band transmitter, a low-noise receiver, display processor, and a high-brightness monochrome display. Transmit characteristics include a pulse width of 40 ns, and a pulse repetition rate of 4096 Hz. The X-band radar operates at 9375 MHz, a frequency affording optimum tradeoff between resolution and weather performance. The 18-foot antenna - housed in aluminum and its front facing protected with a flat section of radome material - makes a compact wind-cutting structure which will operate in 80 knot winds at a uniform rotation rate of 60 rpm. The antenna was designed for ASDE operation with a specified horizontal beamwidth of 0.4° and vertical beamwidth of 12°.

The removal of the marine radar and installation of the ASDE took place between October 21 and December 2, 1996. The ASDE installation retained the marine system's waveguide, dehydrator, power cabling, and a portion of the signal cabling. The pedestal gearing was rebuilt and the 1Hp motor upgraded

to 3Hp to accommodate the 60 rpm rotation and increased antenna drag (wind resistance). All other system components were replaced. Initial turn-on occurred the first week in December. After some troubleshooting, the system was aligned and the system testing commenced. An events log is kept on-site with the system's equipment rack.

After calibration, the evaluation team made system measurements and conducted both functional and operational tests. In order to operate this X-band system on the surface of MKE, the FAA Frequency Management issued a frequency allocation permit (see Appendix F). If a decision is made to deploy this system throughout the NAS, appropriate provisions and/or modifications for frequency restrictions will have to be performed.

Equipment checks and adjustments were made to the radar, specially constructed FTRs were erected near the tower and surveyed with DGPS. Functional tests included measuring parameters of the radar components (transceiver, display, waveguide, antenna), alignment with FTRs, range and azimuth resolution, acoustic noise measurements, and creating airport maps on the display. Data sheets (Section 3.11) provide a checklist summary of all recorded calculations and checked verifications.

5.2 FUNCTIONAL ANALYSIS

After the radar was installed and certified, a functional evaluation of the radar was conducted to verify system performance prior to performing the operational tests. Functional tests were performed to obtain system characteristics and measured values. Parameters of the ASDE-3 and the two Raytheon systems are compared in Tables 5-1a, 5-1b and 5-1c. The measurements made during the functional tests found the system within Raytheon specifications.

The tests were done in three stages (see Section 2.4), partly due to system failures and failed system certification. During certification, functional test measurements taken showed that the Voltage Standing Wave Ratio (VSWR) and pulse width were outside acceptable limits. These problems led to the system modifications and component replacements described below.

Scheduled functional tests, postponed until Raytheon performed system fixes, began on January 13. Completion of the tests was delayed due to weather (resolution test) and scheduled operators' tests. Those functional tests completed served as assurance that effective operators' tests could be performed. Once the operational tests, upgrades, and part replacements were completed, functional testing resumed, and was completed on March 28.

The failed system certification initiated a pulse width modification and a rotary joint replacement. The pulse width, specified as 40 ns, ±8 ns, measured 58 ns. The pulse width directly relates to range cells and range cell distance. A smaller pulse width translates to smaller range cells. With shorter range cells, it is possible to achieve better range resolution. An adjustment to the number of windings on the modulator torroid improved the pulse width to 48 ns, a value within Raytheon specifications.

Modulator failures also delayed functional testing. The first modulator failure (January 26) started as a partial failure, causing the system map lines to misalign from the target returns. The partial failure developed into a full failure, resulting in a complete loss of radar display returns. A new modulator board was installed on January 30. On February 16, a second modulator failure occurred, prompting the request for Raytheon to perform a failure analysis and to ensure continued modulator operation.

Raytheon's failure analysis found that the diodes installed during system production were not properly matched to required specifications. Raytheon hand-picked and installed a set of modulator diodes, and the modulator was replaced on February 18. The system has since operated without interruption.

Table 5-1a. ASDE Antenna / Pedestal Comparison.

PARAMETER	ASDE-3	Raytheon Marine	Raytheon ASDE
Operating Voltage	208 VAC, 3 Phase	208 VAC, 3 Phase	208 VAC, 3 Phase
Running Current (Amps)	7 A	2 A	4 A
Antenna Type	Reflector (CSC pattern)	Slotted Array	Slotted Array
Horizontal 3 dB Beamwidth	0.25 °	0.40 °	0.45 ° ± .05 °
Vertical 3 dB Beamwidth	1.60 °	19.0 °	12.0 °
Polarization	Circular	Circular	Circular
Integrated Cancellation Ratio	17 dB minimum	17 dB minimum	17 dB minimum
Gain	44 dB	36 dB	36 dB
Horizontal Sidelobes	< 5°=-24dB, > 5° =-30dB	< 7.5°=-26dB, >7.5°=-30dB	within ± 10 °, -30dB
Field of View	360 °	360 °	360 °
Scan Rate	60 RPM	22 RPM	60 RPM
Azimuth Position Generator	Encoder	Resolver	Encoder
Motor	5 HP	1 HP	3 HP
Humidity	100 %	100 %	100 %
Operating Temperature	-50° to +70° C	-25° to +65° C	-25° to +65° C
Rotodome / Radome	Rotodome	Rotodome	Rotodome
\Max. Wind Load (Survival)	130 mph	125 mph	125 mph
Max. Wind Load (Operating)	85 mph	80 - 90 mph	80 - 90 mph
Ice Loading	1/2" (Non-operating)	1" (Operating)	1" (Operating)
Dimensions (HxDxW)	10.6'(h) x 18' (diameter)	Antenna = 7.2" x 5.6" x 222" Pedestal = 39" x 32" x 61"	Antenna = 8.7" x 14" x 222" Pedestal = 39" x 32" x 61"
Weight (Antenna + Pedestal)	4800 lb. (incl. rotodome)	320 lb.	340 lb.

Table 5-1b. ASDE Transceiver Comparison.

Key: Vernier labeling in bold italic, e.g., ***GAIN***.

PARAMETER	ASDE-3	Raytheon Marine	Raytheon ASDE
Operating Voltage	208 VAC	120 VAC, 1 phase	120 VAC, 1 phase
Current Load	2.1 A	2.54 A	4.0 A (w/ DP)
Type	Pulse	Pulse	Pulse
Band Designator	Ku	X	X
RF Amplifier	TWT	Magnetron	Magnetron
Peak RF Power	3.5 kW	18 kW (actual)	15 kW (actual)
Average Power	2.2 W	3.8 W	2.9 W
Pulse Repetition Frequency	16384 PPS	3600 PPS	4096 PPS
Frequency	15.7 - 16.2 GHz	9.375 GHz	9.375 GHz
Frequency Agility	16 channels @ 25 MHz	none	none
Pulse Width	40 ns	60 ns	40 ns ± 8 ns
Wavelength	1.8 cm	3 cm	3 cm
Spectrum	-40 dB @ +\- 212 MHz	-40 dB@+82 MHz, -198 MHz	-40 dB@+66 MHz, -147 MHz
Receiver IF	1.25 GHz	45 MHz	60 ± 5 MHz
Receiver Bandwidth	50 MHz	25 MHz	40 MHz
Noise Figure	4.2 dB	6.5 dB	3.5 dB
Frequency Tune	AFC	Manual, TUNE	AFC
MDS	-90 dB	-92 dB	-91 dB
Dynamic Range	30 dB	60 dB	80 dB Minimum
RF STC	Auto	Manual, SEA	Manual, STC
Adaptive Gain	Auto	Manual, GAIN, RAIN	Manual, GAIN, RAIN
Sector Blanking	Yes	Yes	Yes
Area Detection Threshold	2 Adaptive, 1 Fixed	1 Fixed, Manual, FTC	1 Fixed, Manual, FTC
Dimensions	72" x 24" x 24"	33" x 24" x 13"	60" x 27" x 30" [1]
Weight	750 lb.	105 lb.	485 lb. [1]

[1] Dimensions and weight are of entire equipment rack.

Table 5-1c. ASDE Display & Radar Characteristics Comparison.

PARAMETER	ASDE-3	Raytheon Marine	Raytheon ASDE
DISPLAY PROCESSOR (DP)			
Operating Voltage	208 VAC, 3 Phase	120 VAC, 1 Phase	120 VAC, 1 Phase
Current Load	2.1 A	2.0 A	4.0 A (w/ Transceiver)
Update Rate	1 second	2.7 seconds	1 second
Cursor Report	Yes	Yes	Yes
Airport Map Overlay	Yes	Yes	Yes
Range Scale Adjust	Yes	Yes	Yes
Display Info Offset	Yes	Yes	Yes
Multiple Map Storage	Yes	Yes	Yes
Coordinate Conversion	Polar to Cartesian	Polar to Cartesian	Polar to Cartesian
Dimensions (H x W x D)	72" x 24" x 24"	47" x 27" x 30"	60" x 27" x 30" [2]
Weight	625 lb.	216 lb.	485 lb.
DISPLAY			
Operating Voltage	115 VAC, 1 Phase	[See DP]	110 VAC
Current Load	2.1 A	[See DP]	1.5 A
High Brightness	Yes	Yes	Yes
Resolution	1024 x 1024 pixels	768 x 1024 pixels	720 x 1080 pixels
Dimensions (H x W x D)	16 " x 16.5" x 26.5"	[See DP]	19" x 20.5" x 25.5"
Weight	270 lb.	[See DP]	70 lb.
RADAR CHARACTERISTICS			
Number of Point Target Hits Rec'd Between 1/2 Power B/W Points	13	11	5
Safety Interlocks	Yes	Yes	Yes
Waveguide Insert Loss	1.24 dB	2 dB [3]	1.45 dB
VSWR	1.5 : 1	1.14 : 1 [4]	1.253 : 1 [5]
Tower Cab Acoustic Noise	No greater than: 31 Hz = 66 dB, 63 Hz = 71 dB, 125 Hz = 73 dB, 250 Hz = 71 dB, 500 Hz = 72 dB, 1000 Hz = 69 dB 2000 Hz = 57 dB 4000 Hz = 46 dB 8000 Hz = 46 dB	47 dB (A) [6]	System on: 54.5 dB(A) System off: 50.0 dB(A) FMIN = 41.6 dB(A)
Azimuth Resolution	0.25 °	0.40 °	0.4 °
Range Resolution	20 '	60 '	51 '
Azimuth Accuracy	0.04 °	0.087 °	0.088°
Range Accuracy	12'	24'	17'

2 Dimensions are of equipment rack, which contains both transceiver and DP.
3 ASDE-3 value approximate loss for 60' WR - 187 waveguide.
4 Measured from transmitter up to antenna.
5 Measured from transmitter up to antenna.
6 ASDE-3 referenced to FAA-G-2100C; ASDE referenced to FAA -G-2100F: requires no more than 55 dBA.

The functional data summary (see Table 3-8) indicates the system is operating within Raytheon specifications. A full review of the functional data in fact indicates that this system is performing up to--or better than–its specifications. The functional test of the receiver MDS and dynamic range included two separate tests. The first set of procedures using a Raytheon suggested injected pulse width of 250 ns achieved a –98 dBm MDS and a 90 dBm dynamic range. The second procedure performed with a narrower pulse width of 40 ns, better representing the system's transmitted signal, measured a MDS of -97 dBm, and dynamic range of 89 dBm.

X-band radar systems have a predefined limit of acceptability for VSWR of 1.253:1. The MKE VSWR shows the system provides the minimum acceptable value. VSWR first measured by a Raytheon technician during certification was found operating at 1 dB outside the acceptable range. When a suspect rotary joint was replaced, results improved to within the specification. Replacement of a suspected faulty bi-directional coupler could further improve the VSWR measurement.

The antenna beam width and sidelobe levels were measured within specification. The antenna patterns collected verify that the beam width at 3dB down was 0.4°, below the expected 0.45° ± .05° (Figure 3-7). Sidelobes within a 20 degree span in reference to the main beam were measured at 25 dB down from the main beam. Both the vertical and horizontal components of the antenna were measured (Figure 3-8).

Resolution tests (azimuth and range) were performed 1 1/3 nm from the antenna (ATCT) with four trihedral FTRs (two of $3m^2$ and two of $1m^2$). The $3m^2$ targets were fixed while the $1m^2$ targets were moved to establish the minimum resolutions (see Figure 5-1). The azimuth resolution was measured at 49', equivalent to 0.4°; range resolution was measured at 51'. Both measurements are significant improvements over Phase I.

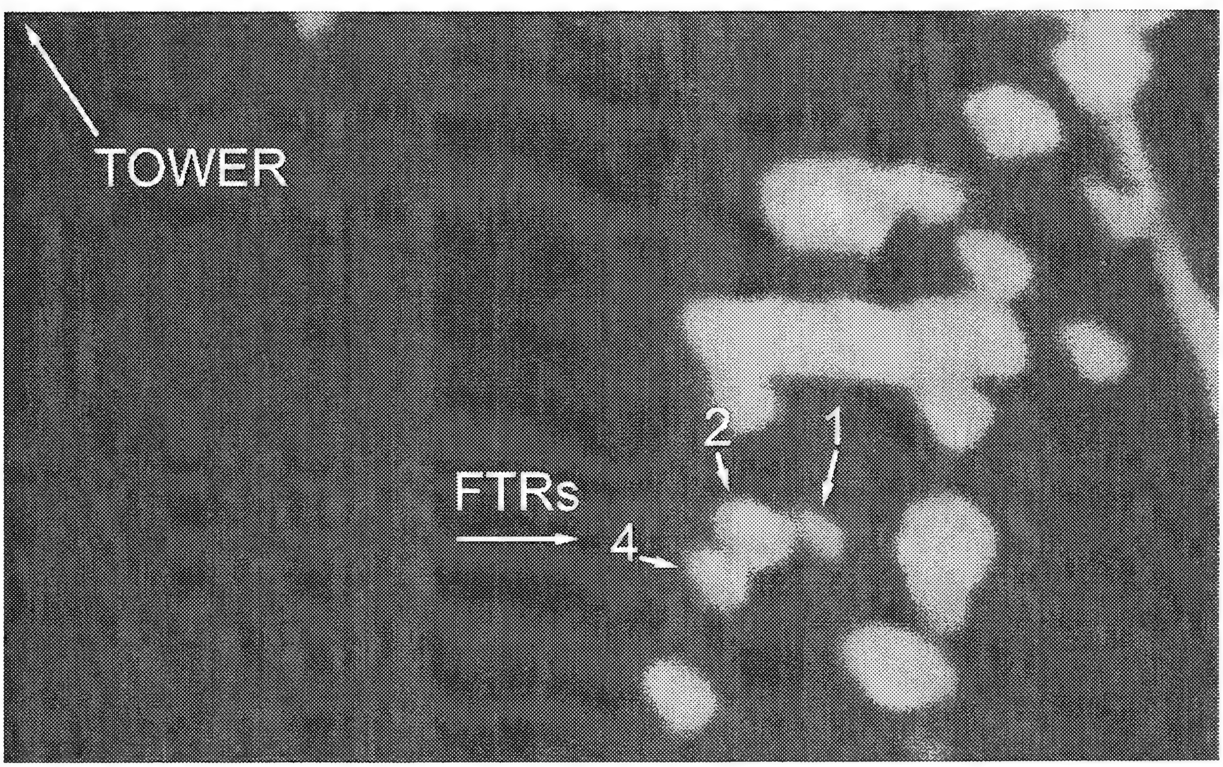


Figure 5-1. Demonstration of Range Resolution (51 ft.) and Azimuth Resolution (49 ft.) (FTR 1,2) (FTR 2,4)

Building Maps and Masks

Part of the reconfiguration of Raytheon's India ASDE to the MKE ASDE included adding a map building utility. The India ASDE system's capability to create overlay maps is in the processor which contains the tracker and safety logic features. The elimination of these features with the processor necessitated the development of a new overlay map utility. The map building utility Raytheon provided with the system can be considered primitive, at best. Although the team was able to produce a map accurate enough for ATC use, it was a long and difficult process[7].

The mask building and editing utility was far better designed and more useful. The team found the mask utility an efficient way to build the radar masking map. One of the team's suggestions for the map building utility update was, "Make it more like the mask utility."

The system is able to store two map files and one mask file in non-volatile memory. The operator had the option of selecting two styles of lines, solid or dashed. Up to 1000 line segments can be stored for each map. The MKE controllers decided to build an overlay map exclusively with solid lines. The two-file option allowed the team to store a master map while creating or modifying the working map. The team built the MKE overlay map using only a small fraction of the 1000 line segments available. The system also lacked map protection; once made, maps were not secure from accidental deletion. Once controllers built their map, they stored it in both files.

The map building process starts on the touch pad. The operator selects the EDIT LINES button on the MAPS page to activate the line drawing feature. The operator positions the cursor at the line's starting point, presses ENTER on the trackball, pulls the line segment like a rubber-band, and presses ENTER to end the line. To delete a line segment, the operator moves the cursor to the line to be deleted and presses CANCEL. Saving and naming maps is also done from the touch pad.

Initial map creation revealed several software bugs and utility shortcomings. The most critical was the cursor's offsetting of map lines. Accurate line placement was hampered by a line shift from the cursor location when pressing ENTER to end the new line. This erratic behavior was dependent on the current offset and range settings. Editing lines was also impossible: they had to be deleted and redrawn. This made creating accurate maps and registering them with an automobile almost impossible. Accurate operator test maps were made by using the masking utility to register runway and taxiway boundaries. With the mask in place, maps were overlaid on the masking lines. The airport map overlay is shown with the masking map on (Figure 5-2a) and off (Figure 5-2b).

Other mapping bugs that became apparent were blinking and misalignments. The maps "blinked" every 60 seconds, an oddity not critical to system operation but annoying to the users. Map-to-video misalignments occurred when maps were rotated from VIEW UP to NORTH UP views. All operator tests were done in the VIEW UP position, the view in which the maps were built. Occasional map-to-mask misalignments also occurred during range and offset changes. The map and mask were realigned by choosing another range or offset setting.

On March 18, Raytheon delivered a firmware update which corrected all of the above bugs. The following week, the test team redrew and registered the map with help from the MKE controllers and an airport vehicle. Map registration consisted of a point-to-point adjustment of the map lines with an airport vehicle. Once registered the mask was realigned to the map. After several days of observations and minor modifications, the controllers certified the map.

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7 Raytheon updated this utility with input from the test team in July 1997. At the same time, Raytheon's second firmware enhanced the map editing utility, allowing map line to line corner modifications without deleting lines.

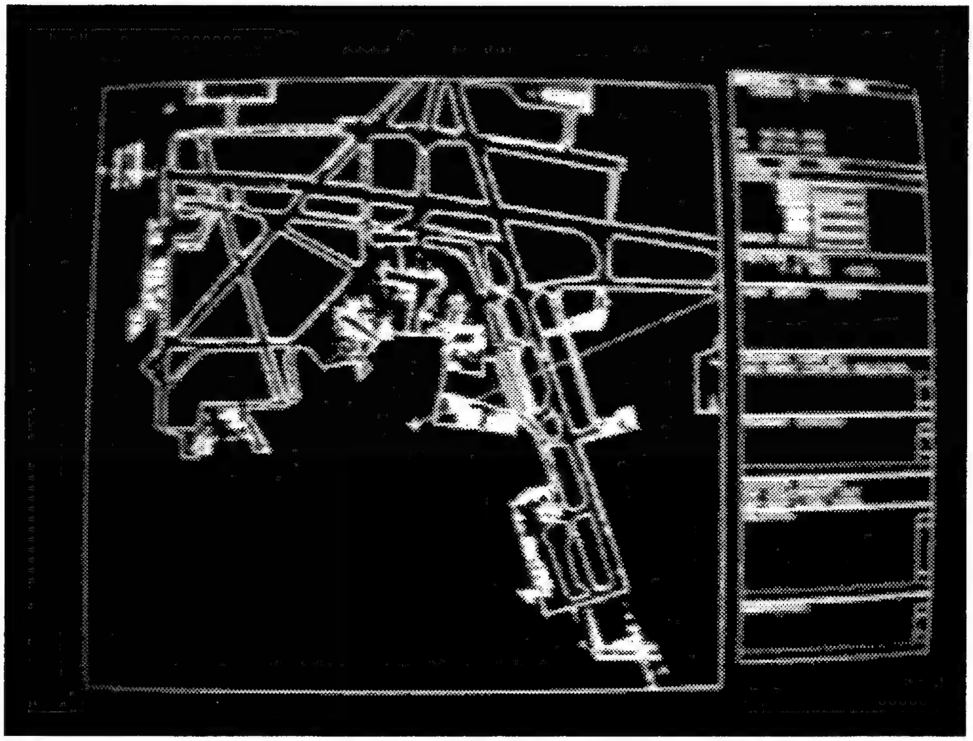


Figure 5-2a. MKE Airport Surface, Mask On.

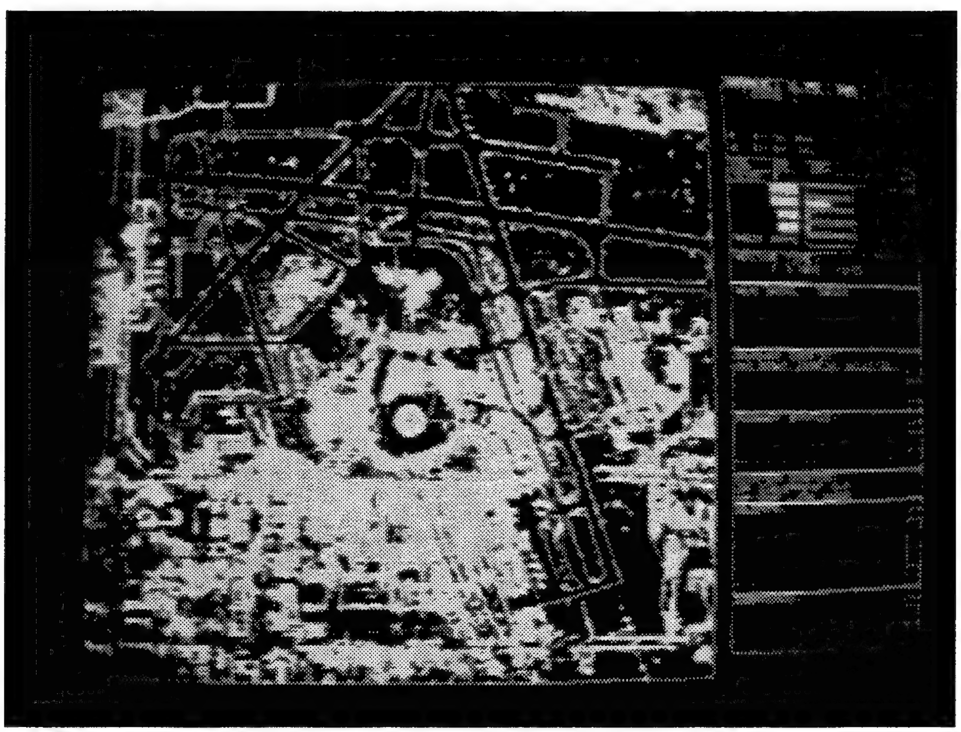


Figure 5-2b. MKE Airport Surface, Mask Off.

5.3 OPERATORS' EVALUATION

The system users--the Air Traffic Controllers--at MKE performed an operator's evaluation of the Raytheon ASDE between January and July, 1997. The evaluation covered aspects of the radar's effectiveness, isolating specific areas of system operation, such as aircraft presentation, target registration, false target display, and user satisfaction covering the system's utility for AT operations. The controllers conducted the test in two stages. The first stage (Sections 4.1 through 4.13) consisted of a formal test where four MKE controllers were trained and then performed a set of predetermined procedures. The second stage (Section 4.14) was an informal evaluation of target clarity during low visibility conditions. The tests used test aircraft, test vehicles, FTRs, and targets of opportunity to verify these and other performance parameters:

- Maximum height coverage.
- Minimum range.
- Demonstration of fast moving targets transitioning from runway to taxiway.
- Demonstration of shadowing between dissimilar sized targets.
- Demonstration of ground targets in reference to map overlay.
- Demonstration of targets during low visibility conditions.
- Observation of display for non-aircraft or false targets.

The controllers recorded the operational test data on test procedure forms and the test team backed up the results on videotape. All written test data and archived videos were analyzed by team members in the preparation of this report. A brief overview of test results appears in Table 5-2.

Raytheon's on-site operator training sessions were considered complete and effective by the controllers, one of whom was the local air traffic training specialist. System operation (see Section 4.13) was straightforward and presented no major problems to the controllers; they later trained the entire MKE ATC staff, who achieved quick proficiency with the radar.

In performing the evaluation, AT verified the radar's capability to detect and display targets in conditions of fog (1/4 nm visibility), moderate rain and snow. The radar enabled controllers to confirm pilots' reported positions and aircraft/vehicle compliance with instructions during low visibility conditions. The controllers' comments regarding the system's overall capability were consistently favorable throughout the evaluation. Though the system has its limitations, the controllers adapted to these limitations and operated the system effectively. The remainder of this section will summarize the controllers evaluation of the system's operation and its appropriateness for the airport environment.

Display Settings (Sensitivity Controls)

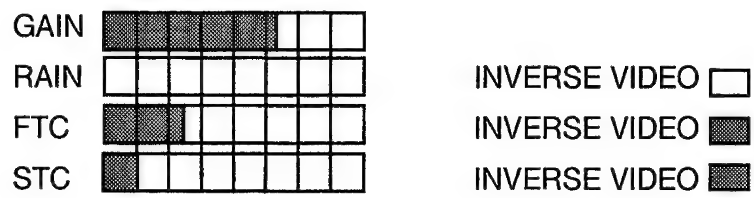
To operate in a variety of weather and surface conditions, the Raytheon ASDE included four sensitivity controls GAIN, STC, FTC and RAIN for maximizing the quality of the radar display. The sensitivity controls allowed the controllers to maximize the desired target returns while minimizing ground and/or rain clutter returns. GAIN adjusted the overall return from targets and clutter. Generally this was set to achieve the desired target size and then the remaining three controls were used to reduce the various types of clutter. Sensitivity Time Control (STC) was adjusted to suppress land clutter and RAIN was defined to suppress rain clutter. The defined purpose of Fast Time Constant (FTC) control was to strengthen weak target returns after adjustments to the STC and RAIN controls were made. Display bars for the sensitivity controls are located on the right side of the display screen.

A fifth bar displays the system's tuning performance. Tuning is maintained by AFC circuitry contained in the transceiver. The tune bar's failure to register during the first two days of the formal testing was related to a partial modulator failure on January 26. Raytheon verified accurate AFC operation with the exception of the display. Once the modulator was changed on January 29, the tune bar display returned and operated normally.

Table 5-2. MKE Phase II Operational Test Results.

T#	*Test Title*	*Responses*	*Remarks On Target Returns*
1	**Maximum Height Coverage**	7 passes	Passes 1, 2 (200, 360 AGL): Targets normal. 3,4 (520, 680): Normal, smaller, Mask off. 5,6 (839, 1000): Normal but weak, small breaks. 7 (1160): Soon lost.
2	**Shadowing, Dissimilar Sized Targets**	14 sightings	No shadowing at any airport locations. Most targets quite distinct, occasional "ghosts".
3	**Registration of Targets on Runway Ends**	22 observations	Good to very good registration on all major runway ends.
4	**Registration of Non-Aircraft Targets**	2 runs	Vehicle targets consistently strong; tandem images merged only within 10' proximity.
5	**High-Speed Turn-off Demonstration**	10 turnoffs	Targets registered consistent and normal on all turns off 25 L / 7 R..
6	**Radar Detection and Presentation**	10 readings	Average delay (1.16 sec) of 10 delays ranging from .93 sec to 1.36 sec.
7	**Target Display Presentation**	24 targets	Mostly OK. One split. Losses below ATCT, A-1 to R. Targets lose size, intensity exiting 1L, Twys B, G, K.
8	**False Target Display Presentation**	8 readings	Consensus that false targets were due to slight misalignment of map, as well as interference due to snow drifts, signage.
9	**Position Accuracy Test**	1 airport tour	Generally OK: some fades around A/C and Cargo Aprons.
10	**Surface Update Rate**	100 updates	Average of 99.01 updates per 100 sweeps.
11	**Probability of Detection**	100 sweeps	Average of 98.3 "hits" per 100 sweeps.
12	**Display Satisfaction**	4 completed	Generally good. Touch pad, some controls (FTC) oversensitive; (see below)
13	**Interface Satisfaction**	4 completed	Generally good, except "tedious, inaccurate" mapping functions; (see below)
14	**Low Visibility Presentation Test**	12 observations	Generally good, despite many fades and losses (see 4.14)
4.0	**Operator Training Assessment**	4 completed	Rated at 90% effective. Thorough presentation of required data. Good manual. Inspired ATC confidence.

For each test, the controllers recorded the display control settings on data forms. During testing, they occasionally adjusted the settings to enhance weak targets or to reduce clutter. Controllers found a tradeoff between these two factors and adjusted the system until comfortable with a presentation that was proper for the airport and current environmental conditions. Once set, sensitivity controls seldom needed further adjustments. The GAIN and FTC controls were those most adjusted, STC the least. The RAIN control was not used at all. The controllers expressed dissatisfaction with the sensitivity of the FTC adjustment. Although the FTC adjustment reduced clutter, a small movement of the adjustment caused drastic changes in the presentation. A more gradual effect spread across the entire adjustment range would make this control more effective. Average sensitivity settings over the operator test battery are shown in below.



Modes of Operation

The system was sold with two modes of operation: normal (Standard) and Moving Target Indicator (MTI). MTI was designed to enhance moving targets (bright video) while suppressing (dim video) stationary targets and clutter. The team's intention was to run all tests in both modes, but it soon became evident that the MTI mode was of no use in airport surface detection. When activated, the MTI mode presented only targets traveling at velocities at greater than 70 knots, i.e., aircraft landing or taking off. All other targets were indistinguishable from the clutter.

Range and Offset Operation

The system provided six range settings, adjusted by increase/decrease range touch pad buttons. Range variations, preset in the maintenance display, were limited to .25 mile increments. The most used settings during the evaluation were .75 nm and 1.0 nm. The controllers stressed that the .75 nm range would be the preferred viewing setting if the entire airport surface fit on the display area. The viewing area is presently limited to the left two-thirds of the display, with the right one-third occupied by a largely unused data field, a holdover from the India ASDE. The minimum range setting to display the entire MKE movement area was 1.0 nm. The controllers suggested that the data field be relocated to the touch pad screen, opening up the entire map screen for the airport at .75 nm. They also would find useful a finer range adjustment capability (.10 nm increments).

The offset feature allows moving the display's center to any location of the movement area–in any range setting, either View Up or North Up–with a simple touch pad and trackball operation. Offset and range adjustments proved most valuable during map and mask building and in the map registration exercise. The fine screen focus to specific areas enabled operators to produce a highly accurate map.

The system also allows six preset offsets. By placing the cursor on a preset circle on the display, the controller can center the map on any of the preselected offset views. The feature is limited to preset range settings. This feature was seldom used during the evaluation. Controllers' desired enhancements include a return to center function.

Maximum Height

The controllers evaluated the maximum height of target detection over the airport. The test team wanted to measure height performance of the system for possible future installations. Raytheon's specified 3 dB beamwidth of 12°, the tower height of 204.5 feet, and the controller's visibility map were used to estimate system coverage. A HS-25 Hawker/Siddely was flown over Rwy 19R-1L to test maximum height coverage at 200, 360, 520, 680, 840, 1000, and 1160 feet AGL. Maximum distance from the antenna (runway end 1L) was approximately 1 1/4 nm. Minimum distance was just over 1/2 nm.

The HS-25 registered a strong target across the entire runway at 200 and 360 feet AGL traveling at 130 knots. The 200-foot coverage in the ASDE-3 specification would provide no problem for this system on any of the potential low-cost ASDE installation sites. The target weakened but still registered across the entire runway up to 680 feet AGL. At 839 and 1000 feet, the target was lost over areas closest to the tower. These better than expected results, with reported poor coverage in front of the terminal areas,

led to the suspicion that the antenna could be tilted upward. A minimum range test (.25 nm) and a re-examination of the antenna alleviated these concerns.

Shadowing Due To Dissimilar Sized Targets and Buildings

Controllers examined various lineup areas where aircraft often travel in tandem. During Test 2 (see Section 4.2) a small aircraft was lined up radially with a larger aircraft in potential problem areas and their relative displays noted. No problems were noted with shadowing of targets, in either the formal test or through observation of targets of opportunity. The height of the antenna and the MKE layout preclude any major shadowing problems when aircraft are lined up. Figures and data in Section 4.2 show examples of distinct target registration between the test aircraft (C150 and HS25) to be the norm.

Shadowing from terminal buildings, however, were noted during Test 9, Position Accuracy Testing. Controllers often reported targets "lost" or "fading" as they traveled close to terminals. Hangar areas also accounted for shadowing occurrences, such as the Cargo Ramp, USAF Reserve, East hangers and Signature North. Targets traveling in these areas were often "lost" behind buildings or among parked aircraft.

False Targets

Airport terminals, hangars, and other support buildings, as well as parked aircraft, are common causes of multipath situations and false targets on radar screens. Changing surface conditions can also produce false targets. The evaluation of the MKE ASDE for false targets was hampered by several factors including the map and mask inefficiencies described above, poor map and mask registration, two modulator failures, and a snow-covered airfield. The false targets observed during testing were mostly associated with radar returns from signs and lights registering inside taxiway and runway lines. Significant returns from the snowbanks were also recorded. Once the snow melted and maps and masks were properly aligned, the system presented a clean display.

Two false targets not due to signage, lighting or snow banks included a stationary target painted on Twy E between Twys M and K (Figure 4-10) and a split return from an airplane traveling north on Twy B (Figure 5-3). The split or false target traveled on Twy E mimicking the movements of the real target. All the false targets were temporary and were dependent on surface conditions and/or on aircraft parked at the terminals.

High-Speed Transition

As aircraft exit (transition) from runways to taxiways, their radar cross-section varies with the aspect angle to the radar changes, potentially causing target loss or fade. High-speed turns demonstrated at Rwy/Twy intersection 25L/A2 were limited by airport surface conditions during test week. No major problems were reported during this test. All transitions made at normal speed (10–25 knots) were reported as normal (Figure 5-4). Controllers occasionally recorded fading of target strength when aircraft or vehicles were turning, or when checking position accuracy.

Non-Aircraft Targets Traveling In Tandem

The controllers evaluated the system's ability to separate ground vehicle targets by observing a county snowblower and pickup truck traveling in tandem on taxiways and runways. Convoys of snow removal equipment were also observed. Distances recorded were estimates given by the vehicles operators. Observations showed that only when vehicles traveled in very close proximity (less than 20 feet) their images would fuse into a single target (see Section 4.9). When the test observer asked the drivers to separate, the targets became distinct at approximately 50 feet. Note also several large aircraft parked on the USAF Reserve lot. Figure 5-5 shows a convoy of six snow removal vehicles approximately 50 feet apart.

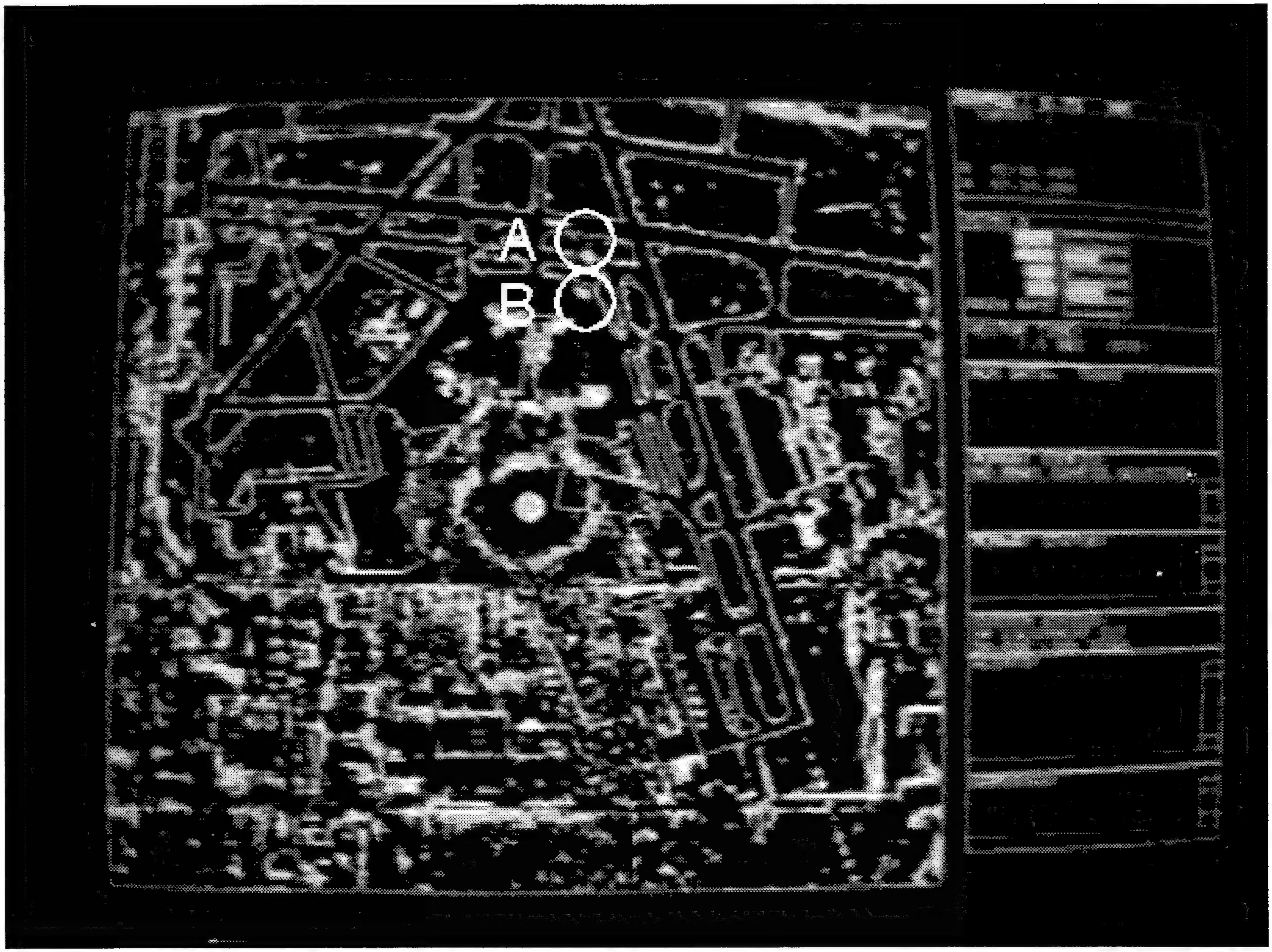


Figure 5-3. Split Target: True Target (A) on Twy B, False Target (B) on Twy E.

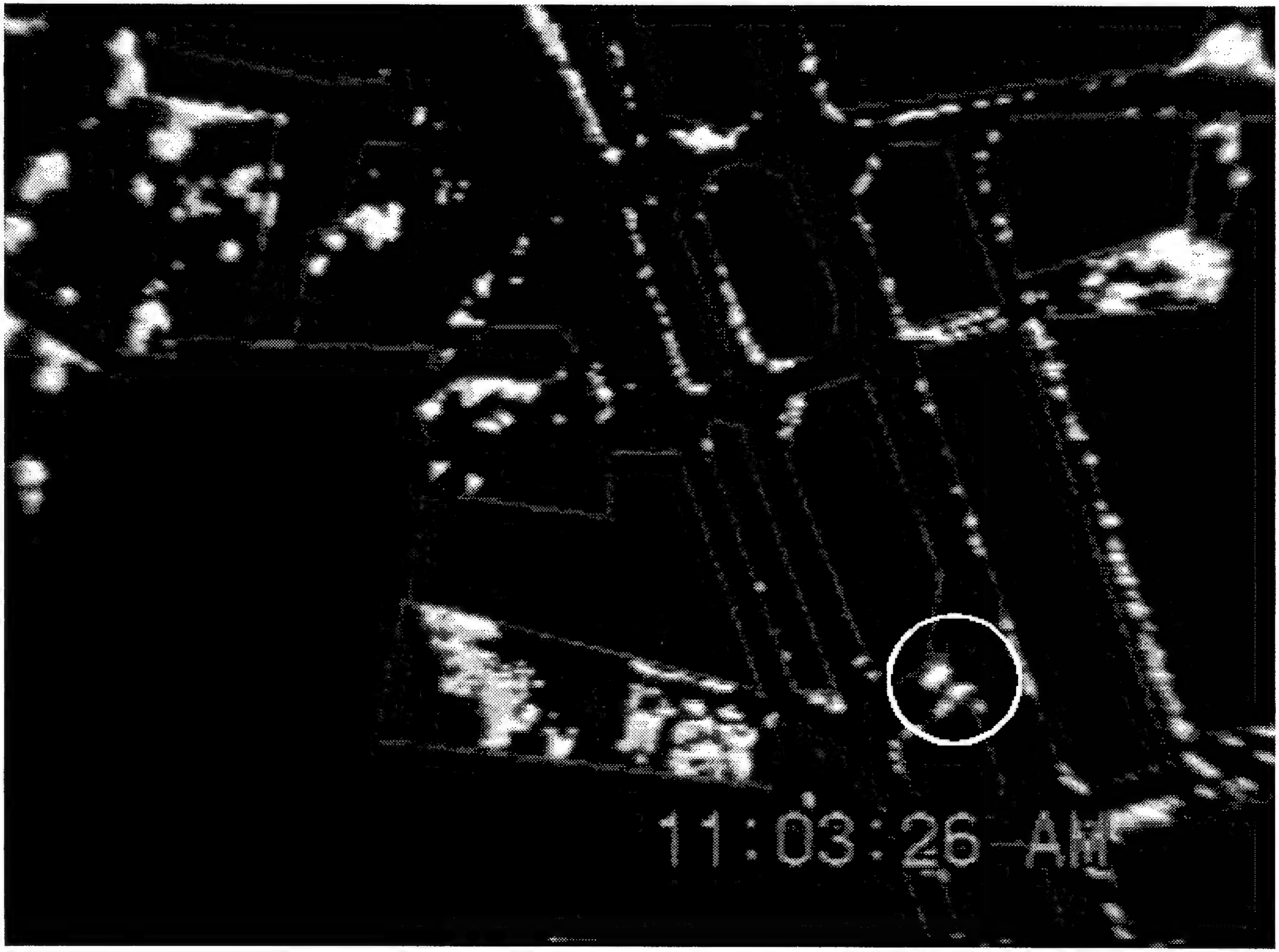


Figure 5-4. Target in Transition from Rwy 25L to Twy A2.

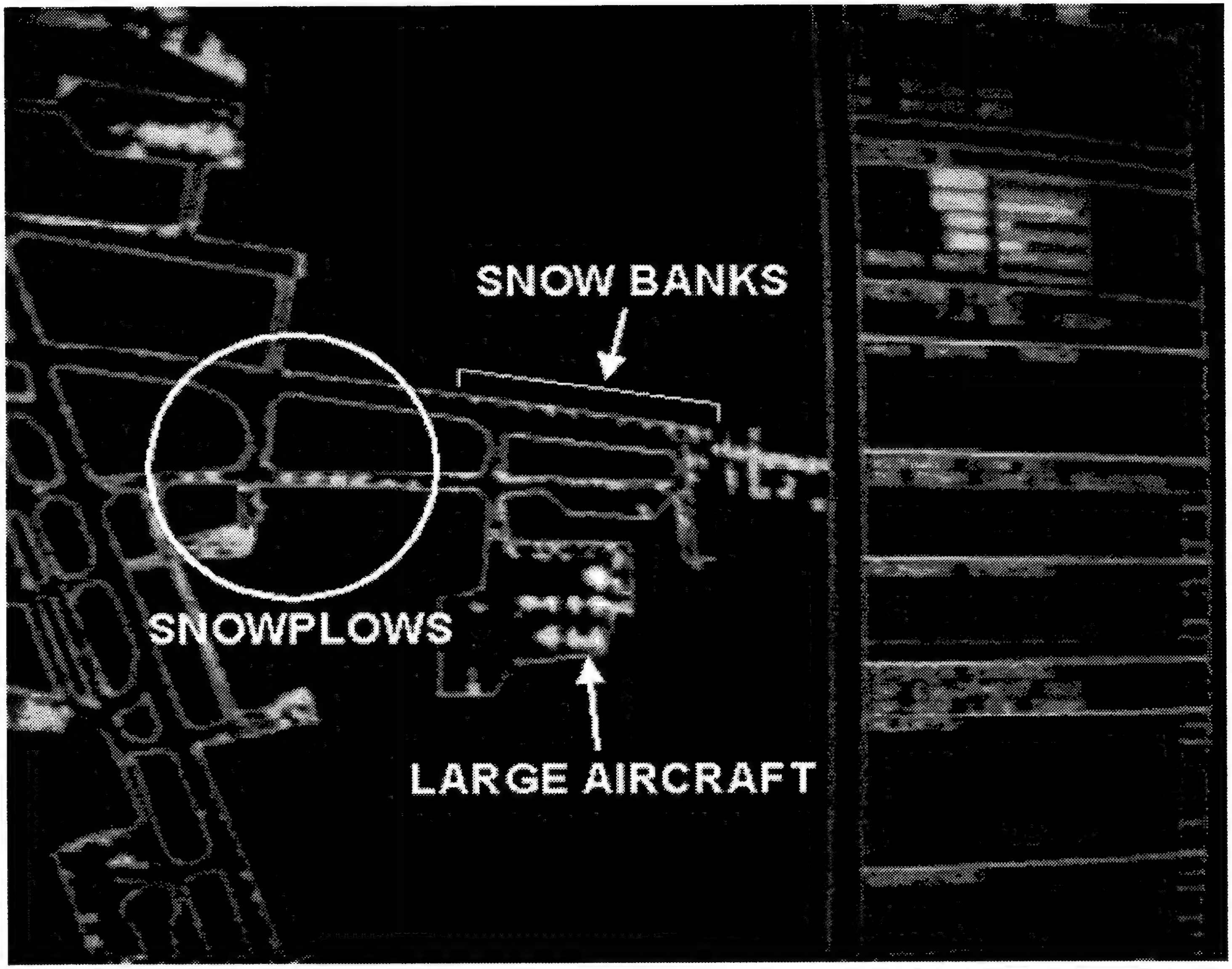


Figure 5-5. Snowblower/Vehicles Traveling South on Twy R.

Radar Detection and Presentation

The average time delta of an approaching aircraft's crossing the runway end to its presentation on the screen was measured at 1.16 seconds. The time reflects the limits of the system due to the rotation rate and processing delay. The controllers measured the antenna rotation rate at approximately .99 seconds, or the expected 60 rpm. Probability of detection of a $3m^2$ target (FTR) at 1 1/3 nm was measured as 98.3 %.

Controller Satisfaction with Display and System Usefulness

The four controllers testing the system commented on system usability through questionnaires in the Operator's Evaluation Plan. Overall the controllers liked working with the system. The screens were clean and targets could be seen on all of the airport movement area. The controllers also saw a need to improve some aspects of the display controls and suggested some functional enhancements.

The controllers agreed that the system layout in the tower cab needed improvement. (The temporary test setup of high brightness display, touch pad and trackball was intended to preserve the original tower condition.) The controllers liked the flexibility of the retractable display arm which moved the display up and out of view when not in use, and down to eye level when in use. The one complaint about the arm was the difficulty in locking and unlocking it from its storage position. During the evaluation, the installer relocated the locking mechanism to console level, which proved satisfactory. The high brightness display allows readability under all cab lighting conditions. The controllers liked being able to adjust the brightness of data and maps separately from radar returns, allowing them to de-emphasize ancillary data and highlight aircraft and vehicle returns.

The current split-level trackball and touch pad setup is uncomfortable for the controllers. For a permanent installation, this control suite should be built into the console. The brilliance of the original touch pad, which had no dimmer adjustment, became an annoyance during nighttime operations in the cab. Controllers soon covered it in an attempt to reduce the excessive light. Raytheon's first attempt to resolve this issue by inverting the video (green print on black) made the touch pad unreadable by day and still too bright at night. An installed rheostat lacked the adjustment range to lower the brightness for nighttime operations. Raytheon is continuing to research this issue. The controllers report touch pad sensitivity as a problem: single touches can cause multiple system adjustments.

The controllers had many suggestions concerning the layout of the display and the touch pad screen. Foremost was the maximization of the display area for the airport layout. The one-third of the display reserved for the display of system data would be better used for the radar target presentation (Figure 5-6). They suggest moving the data field to the touch pad. The controllers considered the data field an obstruction to achieving the optimum view of the radar returns. They suggest moving the data field to the touch pad. The controllers also asked for single-page access to all primary touch pad functions. This measure would help minimize the controllers' "head down" time. It is unacceptable to ask controllers to page through screens while controlling traffic. All setup and maintenance level commands should be moved to a lower level. A controller-suggested layout for the display and touch pad is shown in Figure 5-7.

Range/Bearing, Cursor Marks, IR, and Target Trails

The system was provided with functions which were useful for the setup and maintenance of the system but which were seldom used by the controllers.

The range/bearing functional allowed the user to view range and bearing in nautical miles and degrees from north of any position on the screen. This function was useful in checking radar alignment with a surveyed position.

Cursor marks and auxiliary lines allowed users to mark the display with quick reference points, an aid in checking system alignments.

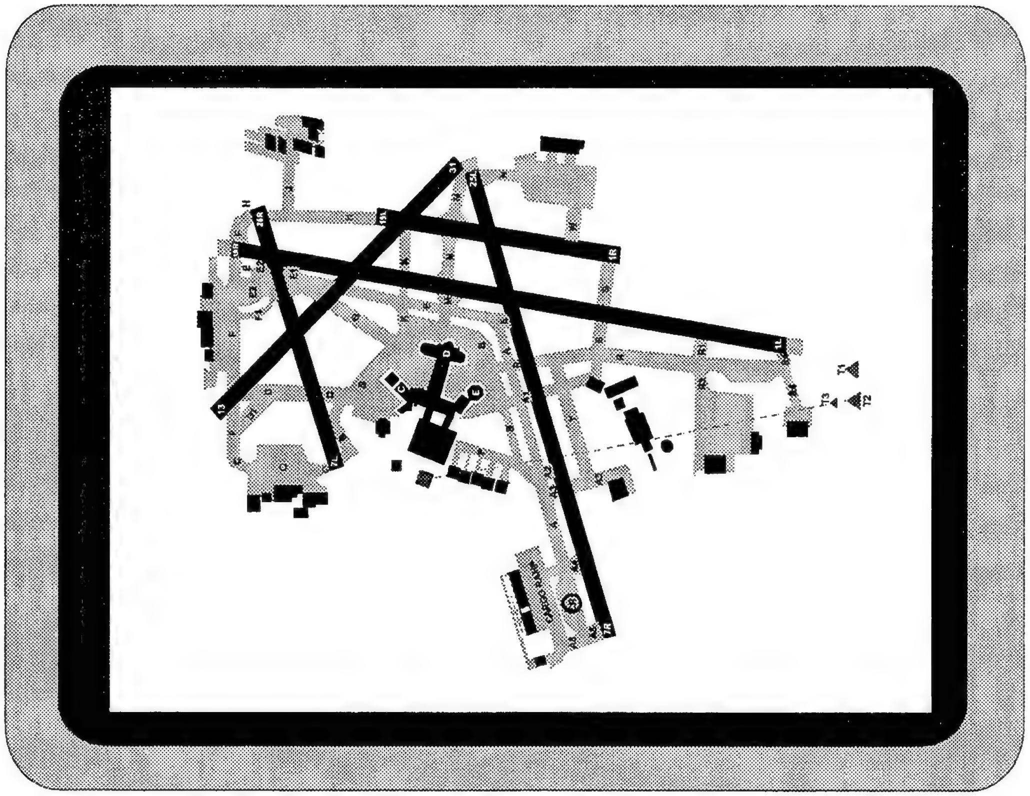


Figure 5-6. Airport Map on Display.

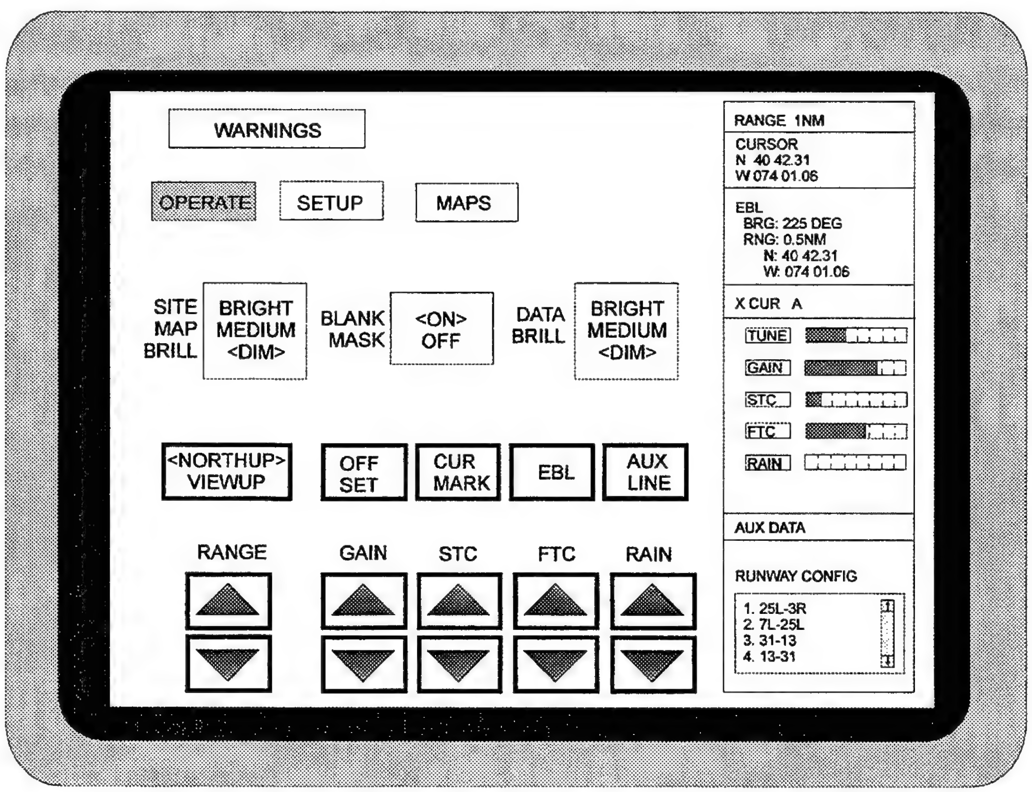


Figure 5-7. Touch Pad Display (Operate Page).

The Interference Reduction (IR) function was left on during testing, as it eliminated occasional "spoking" that appeared on the screen.

Target trails gave the ability to display remnant paints in three options; short, medium and long. It was rarely used by operators. Trails could potentially obscured separation of targets in tandem.

5.4 RECOMMENDATIONS

SUMMARY OF SUGGESTIONS

The radar sensor is the strength of the system. Its ability to detect and resolve targets make it a suitable ASDE solution. The ASDE allowed operators to achieve a clean presentation and display targets of all sizes throughout the airport surface. The masking function, invaluable in suppressing unwanted clutter returns, allowed a quick shut-off in an emergency to view previously masked areas.

The operator's interface needs some work as stated by the test controllers throughout the test. Controllers' suggestions for improving system operation include the following:

Built In Test (BIT): The Performance Monitoring Unit (PMU) was eliminated from the Milwaukee configuration when the redundancy and tracker features were removed, and the BIT capability became non-functional. Future ASDE systems will require BIT capability for maintenance and operation support.

Preset Configurations: The controllers want to be able to create at least 20 preset configurations, including display setups for system traffic flow configurations, weather scenarios, and/or user preferences.

Color Displays: The controllers stressed that a color display would enhance the system's presentation. Enhancing the map with color would further highlight the airport's movement areas.

Autocad Map and Mask Overlays: Potentially the maps and masks can be lost during a system failure. Loss of the maps would require a long mapbuilding session using the system's current inefficient map editor and pressing into service an airport vehicle for many hours. The ability to store saved maps and to use Autocad drawing for map building would improve system usability.

Elimination of the Touch Pad: The operators have expressed the desire to go to a "Windows" type interface, using a mouse and pull-down menus for operation. Secondary windows are also considered a worthwhile enhancement.

MTI Adjustment: The present MTI configuration was considered useless by the controllers. They would like to highlight moving targets down to zero velocity and to hold stationary targets highlighted as long as they want. This feature would be valuable during high clutter situations, such as snow pileup on the airport surface.

RAYTHEON'S NEXT GENERATION ASDE DESIGN

Raytheon is currently redesigning their control processing to better accommodate the FAA and what is perceived as the future of low-cost ASDE. Below is a brief summary from a Raytheon presentation to the FAA. This is meant to give the reader a look at possible improvements to future systems.

The future Raytheon ASDE will include the ability to accept data from other sensors (i.e., ARTS, millimeter wave sensor, etc.), fuse the data, and present it on a single display. The system will also include the ability to host a tracker and process data with safety logic algorithms.

System setup options will include the capability of a fully or partially redundant configurations dependent on an individual airport's needs (see Figure 5-8.) These options can include redundant radar display processors (DP), transceivers, and dual LANs connecting the DPs with multiple controller display workstations.

Hardware for the DPs and display workstations will be based on COTS design and are X/Open and POSIX compliant. The radar display processing will be updated with a Constant False Alarm Rate (CFAR) capability; CFAR aids in clutter suppression and eliminates the need for adjusting manual sensitivity controls (GAIN, FTC, STC and RAIN).

Controller displays will be X-windows based, eliminating the need for a touch pad, and transferring control and configuration to on-screen menus. The display system will give controllers the option of displaying video only, track only, or simultaneous display of both. Other capabilities will include display of up to 16 open secondary windows, full-screen panning, incremental zooming, and incremental display rotation.

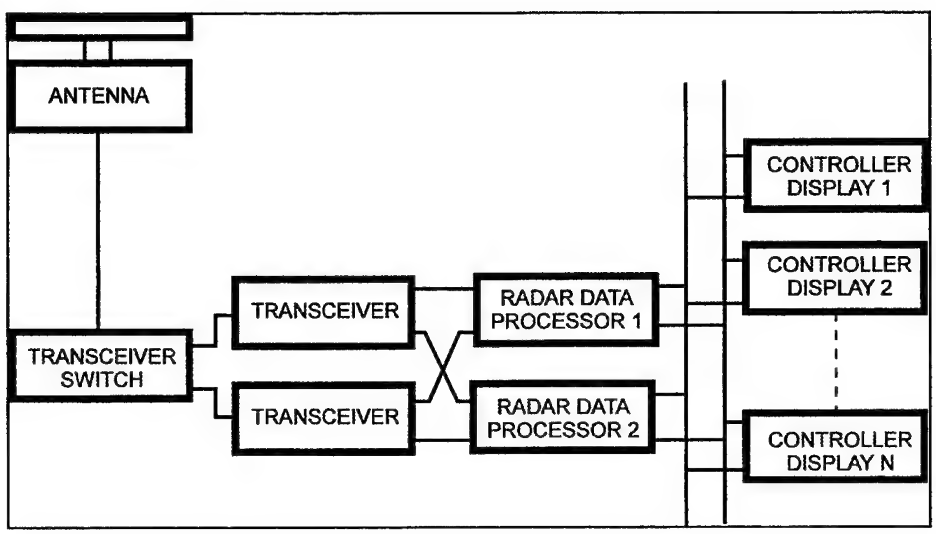


Figure 5-8. Future ASDE Architecture.

Map making will be enhanced with a radar snapshot analysis tool allowing increased accuracy over scanned drawings methods and the current manual drawing from scratch technique. Masking or blanking will be done with up to 500 polygons.

APPENDIX A

ALIGNMENTS

The radar alignment procedures were performed after system installation was completed, and before functional testing began. These alignments ensure that the system is operating at peak performance. Alignments should be performed in the order given below, starting with the transceiver, progressing to the slow start and display processor units, and finally the full system.

Transceiver alignments (Section A.1) are a series of adjustments to the high voltage power supply, the automatic frequency control (AFC), the STC, video and data levels, and end with a minimum discernible signal (MDS) test.

The slow start unit alignments (Section A.2) involve solid state overload, current limit, acceleration ramp time, and phase loss adjustments.

Display processor alignments (Section A.3) contain alignments to the +5, ±12 power supply, switch panel logic alignments, interswitch alignments, and performing the noise threshold and FTC zero adjustments.

Finally, full system alignments entail aligning the radar to three aluminum fixed target reflectors (FTRs) with known, precise positions on the MKE surface. These alignments, found in the radar registration section (Section 3.7.3), are the antenna offset and zero range tests. The final alignment for the system permits the critical creation of accurate display maps, following instructions in Map Generation (Section 3.8).

A.1 TRANSCEIVER UNIT

Transceiver alignments are a series of adjustments to the high voltage power supply (Section A.1.2), the automatic frequency control (AFC) (Section A.1.3), the STC (Section A.1.4), video (Section A.1.5) and data levels (Section A.1.6), and end with a minimum discernible signal (MDS) test (Section A.1.7).

A.1.1 INITIAL SETUPS

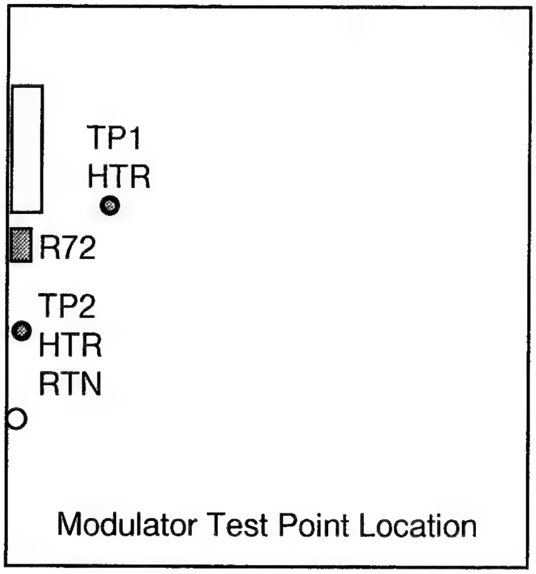
1. Ensure MTR is connected to the antenna prior to alignment.

2. Place MTR CNTRL switch to ON, place XMIT CNTRL to STBY and place TRIG CNTRL to AZ LOCK at the MTR control panel.

A.1.2 HIGH VOLTAGE POWER SUPPLY ADJUSTMENTS

1. Remove cover from modulator.

2. Adjust magnetron filament voltage adjust R72 on the Modulator PCB for 6.6 VDC measured at TP1 (HTR) and TP2 (HTR RTN).



Modulator Test Point Location

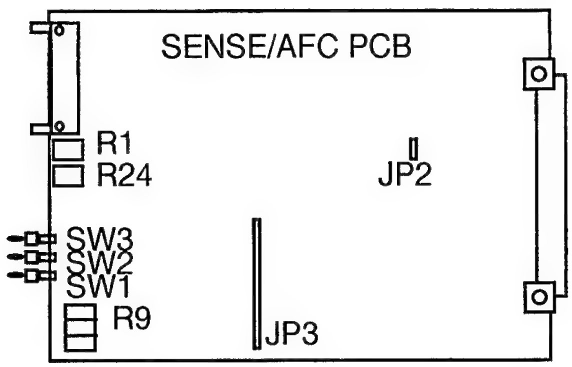
3. Place XMIT CNTRL on MTR control panel to TXON and use UP/DN buttons on the MTR control panel unit to display Mag I.

4. Adjust R212, (800 VDC) on the top right corner of the power supply until the magnetron current on the MTR control panel display reads 6.8 A, and perform Forward Transmitter Power Output measurement.

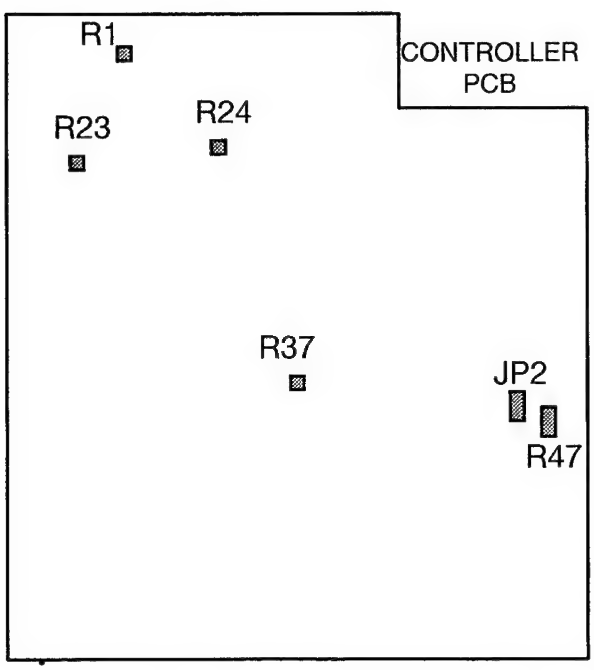
5. Replace cover to modulator.

A.1.3 AUTOMATIC FREQUENCY CONTROL (AFC) ADJUSTMENT

1. Turn MTR to standby and allow magnetron to warm up for 1 hour.
2. Put system in TX ON.
3. On the MTR control panel use UP/DN buttons to display TUNE IND percentage.
4. To coarse tune the AFC, place SW1 & SW2 to right, and SW3 to left on the SENSE/AFC PCB.



5. Adjust R37, tune offset on the Controller PCB until the indication on the MTR control panel display is at its peak.



6. To fine tune the AFC, place SW1 & SW3 to right, SW2 to left.
7. Adjust R1 on the AFC PCB until a peak is shown on MTR control panel display.
8. Set the AFC to auto tune (SW1 to right, SW2 & SW3 to left). The AFC is now engaged and tracking.

NOTE: The following adjustments are for the MKE ASDE installation only.

A.1.4 STC ADJUSTMENT

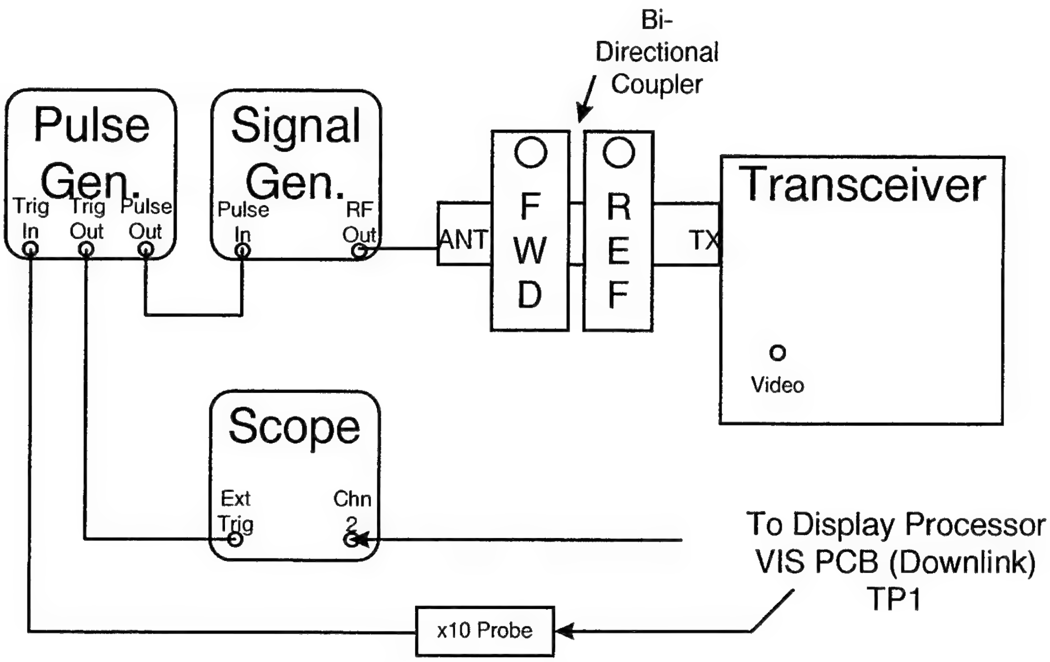
1. Turn off radar system and **disconnect magnetron filament connection**. This is the white cable from the modulator board to the magnetron, with a red filament light indicating power to the magnetron.

2. Remove modulator cover.

3. On the MTR control panel of the MTR, place XMIT CNTRL switch to XMIT and MTR CNTRL switch to ON.

4. Disable AFC of the receiver by setting SW2 to the right AFC Sense PCB.

5. Configure test equipment as shown below.



6. Set RF source to 9375 MHz, CW mode. Connect power meter to output end of test cable. Set RF source output power controls to 0 dBm.

7. Trigger the pulse generator (through 10X probe) from the downlink video.

8. Set the trigger controls (level and polarity) of the pulse generator to trigger on the positive trigger portion of the downlink video.

9. Set oscilloscope controls to trigger on the leading edge of the pre-trigger pulse of the downlink video.

10. Adjust R23 on the controller PCB for minimum delay (fully clockwise).

11. Set RF source to PULSE.

12. Set pulse generator for a pulse width of 1μsec delay, and a 0.1 μsec duration.

13. Set oscilloscope for a 2 μsec time base and vertical sensitivity of 1V/division.

14. On RF source, reduce the RF output level by 33 dBm.

15. Using a convenient reference point on the oscilloscope, note the highest level of the STC curve.

16. On RF source, adjust RF output level to 0 dBm.

17. Adjust R24 on the controller PCB so the lowest level of the STC curve reaches the same point as the highest level noted in step 16 above.

18. On the AFC Sense PCB, place SW2 to the left.

19. Place MTR CNTRL to OFF.

20. Replace modulator cover.

21. Reconnect magnetron filaments

22. On the MTR control panel, turn MTR XMIT CNTRL switch to STBY.

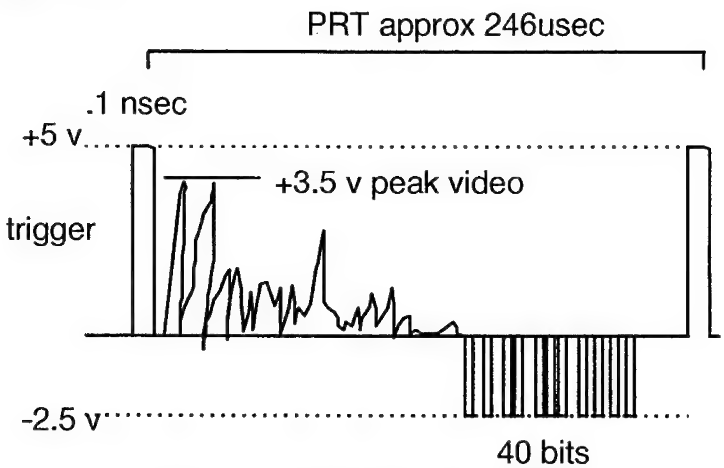
23. On the MTR control panel, turn MTR CNTRL switch to ON.

24. Wait 3 minutes, place MTR XMIT CNTRL switch to TX ON.

A.1.5 ADJUST VIDEO LEVEL

WARNING: High voltage is present at the magnetron during R1 adjustment.

1. Connect an oscilloscope to observe the downlink at bottom of R47 (on Controller PCB). See figure below.



NOTE: Horizontal not to scale!

2. Adjust R1 on controller PCB to set “main bang” level for approximately +3.5V.

A.1.6 ADJUST DATA LEVEL

1. Adjust R14 to set the downlink negative data level at -2.5V as observed at J14 pin 4.

2. Perform MDS measurement. See Section 3.5.5.

A.1.7 MINIMUM DISCERNIBLE SIGNAL (MDS) TEST

See Section 3.5.5.

A.2 ANTENNA SLOW START

The slow start unit alignments involve solid state overload (Section A.2.1), current limit (Section A.2.2), acceleration ramp time (Section A.2.3), and phase loss adjustments (Section A.2.4).

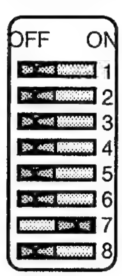
A.2.1 Solid State Overload

Switch Number	Description	Left (OFF) (amps)	Right (ON) (amps)
1	Current	8	12
2	Current	0	2
3	Current	0	1
4	Current	0	.5
5	Current	0	.25
6	Current	0	.25
7	Energy Saver	Disabled	Enabled
8	Shorted SCR	Enabled	Disabled

1. Rectify OverLoad (OL) or fault condition before resetting the slow start unit. This is accomplished by pushing the RESET button approximately 200 seconds after an OL trip. The RESET button is located on the slow start unit cover.

2. Use DIP switches to set Motor Full Load Current (MFLC).

3. Adjust between 8 and 16 amps, in .25 increments. Need help figuring out what current to set.



A.2.2 Current Limit Adjustment

1. Adjust current limit using potentiometer located behind the cover.

2. Current limit can be set between 150% and 425% of MFLC. This adjustment limits the motor current to the set level at all times during acceleration and run conditions. It also works in conjunction with the acceleration time adjustment to provide various starting characteristics.

A.2.3 Acceleration Ramp Time Adjustment

Acceleration ramp time is adjustable (clockwise or counter-clockwise) between 0.5 and 30 seconds via a potentiometer located behind the cover. Actual motor acceleration time is a function of motor loading and current limit setting, as well as acceleration ramp time setting.

1. Open MTR cabinet rear door and remove cover of antenna slow start unit.
2. Remove cover from antenna slow start controller unit.
3. Adjust acceleration ramp time adjustment fully counter clockwise.
4. Adjust clockwise to obtain full rotation speed in approximately 2 seconds from turn on.

A.2.4 Phase Loss

If one or more phases are missing at line terminals L1, L2, or L3, the phase loss LED will light, and the slow start unit cannot be energized. Restoring the missing phase will automatically reset the antenna slow start unit.

A.3 DISPLAY PROCESSOR

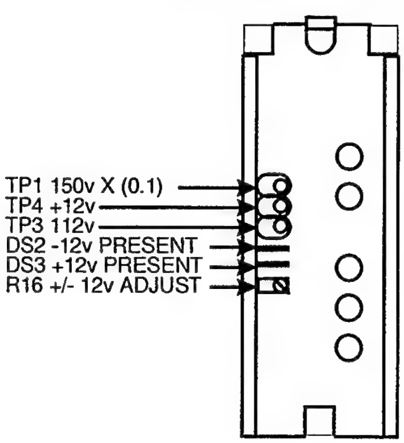
Display processor alignments contain alignments to the +5, ±12 power supply (Section A.3.1), switch panel logic (Section A.3.2), interswitch (Section A.3.3), and adjustments to the noise threshold (Section A.3.4) and FTC zero (Section A.3.5).

A.3.1 +5, ±12V POWER SUPPLY OUTPUT ADJUSTMENTS

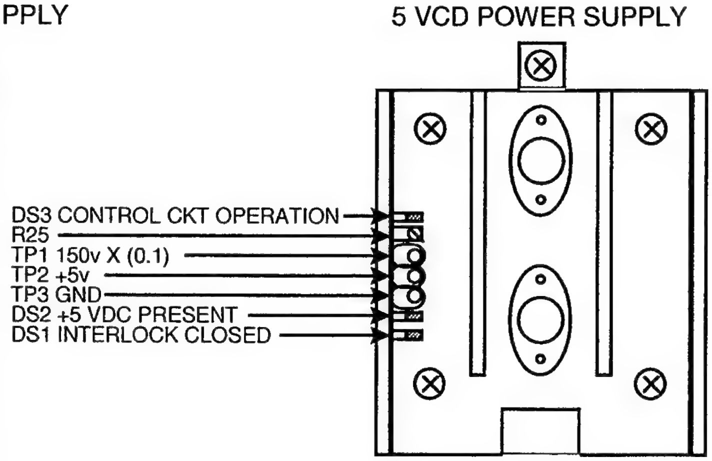
All display processor power supply outputs are set at the factory and normally should not require adjustments. If the output voltages are incorrect adjust the power supplies for the correct output as specified below.

Test Point	Adjustment	Output Voltage
TP2(orange)=+5 VDC to TP3(black)=GND	R25	+5 VDC ± .05
TP4(red)=+12 VDC to GND (Use chassis) TP3(red)=-12 VDC to GND (Use chassis)	R16	Adjust for a balance between +12 VDC and -12 VDC

12 VDC POWER SUPPLY



5 VCD POWER SUPPLY



A.3.2 Switch Panel Logic Adjustments

Test Point	Adjustment	Output Voltage
+Out = +5 VDC to GND (Use chassis)	R9	Adjust for +5 VDC ± .05 VDC
+Out =+12 VDC to Common	R20	Adjust for +12 VDC ± 0.1 VDC
-Out =-8 VDC to Common	R26	Adjust for -8 VDC ± 0.1 VDC

A.3.3 Interswitch Alignments

1. At the display processor, adjust R3 on the VPA PCB midrange.
2. Connect an oscilloscope to TP3 on the VPA PCB.
3. Adjust the gain potentiometer R9 on the AIS PCB midrange.
4. Adjust R3 on the VPA for 2.5V of non saturating peak video.

A.3.4 Noise Threshold

NOTE: Ensure the radar is properly tuned, and VPA alignment (R3) is correct before proceeding with the following adjustment.

1. Turn off system.
2. Remove bi-directional coupler, and connect dummy load to transceiver unit.
3. Reset system with transceiver set to STD BY.
4. At touch pad, enter tests.
5. Use the trackball and move the cursor to select Test 5.3 - NOISE THRESHOLD, and press the left (Enter) button on the trackball.
6. Switch the top switch of the ARP PCB to the left.
7. Select the 3nm viewing range.
8. Turn the RAIN/FTC and STC controls OFF.
9. Just crack the FTC (letters back lit).
10. Set the GAIN control so that the bar graph deflects to mid-range.
11. Set transceiver unit to TX ON.
12. Press * on the touch pad keypad.

    NOTE: The following procedure adjusts the noise speckle using the GAIN control. With the exception of the immediate area surrounding the radar site, the adjustment criteria is an even speckle density of noise across the entire display at the dim level (reduced ambient lighting may aid in this determination). Noise density should be equal on all ranges.

13. While observing the area near the outer edge of the radar display area, adjust GAIN control for equal noise speckle at the dim level with only a random number of hits breaking into the high level. (The gain should be changed in increments, allowing for 3 scans between each setting before observing the results).

14. When the presentation is correct, press E on the touch pad.

15. Return to the normal operating screen by pressing the right (Cancel) button on the trackball. Set the GAIN control to fill six divisions on the bar graph.

16. Check all ranges to ensure that noise speckle does appear, but does not change greatly as you change range scales with fixed setting of the GAIN Control. Observe that the screen will not saturate when GAIN is set to maximum. If necessary, return to step 1, and correct those ranges on which the noise threshold proved incorrect.

17. Proceed to next adjustment, E.3.5, FTC Zero Adjustment.

A.3.5 FTC Zero Adjustment

1. Follow Noise Threshold procedure, E.3.4.

2. Go to normal operation, make sure masks are off. FTC should still be just cracked.

3. Adjust GAIN for a light speckle.

4. Turn off the FTC.

5. Adjust R40 on the VPA PCB for the same noise level as in step #3. Go back and forth between FTC OFF and just cracked, to check that the levels are the same.

6. Set ARP switch to the right hand position.

7. Turn off system.

8. Remove dummy load and reinstall bi-directional coupler.

9. Return unit to normal operation condition.

A.4 SYSTEM

Full system alignments entail aligning the radar to three aluminum fixed target reflectors (FTRs) with known, precise positions on the MKE surface. These alignments, found in the radar registration section (Section 3.7.3), are the antenna offset and zero range tests. The final alignment for the system permits the critical creation of accurate display maps, following instructions in Display Map Generation (Section 3.8).

A.4.1 Radar Registration

This test verifies that the system displays the correct bearing and range of a target. See Section 3.7.3 for the Antenna Offset Test and Zero Range Test.

A.4.2 Display Map Generation

This test demonstrates how to make a map, both generally, and specifically for the airport. See Section 3.8 for map building and maskmaking procedures.

APPENDIX B

METAR INSTRUCTIONAL INFORMATION

A new international aviation routine weather reporting code called METAR is now being used by all countries of the world. The following is a description of the METAR code. The elements in the body of a METAR report are separated with a space. The only exception is temperature and dew point. Which are separated with a solidus, /. When an element does **not** occur, or cannot be observed, the preceding space and that element are omitted from that particular report. A METAR report contains the following sequence of elements in the following order and described in paragraphs that follow:

1. Type of Report
2. ICAO Station Identifier
3. Date and Time of Report
4. Modifier (as required)
5. Wind
6. Visibility
7. Runway Visual Range (RVR)
8. Weather Phenomena
9. Sky Conditions
10. Temperature/Dew Point Group
11. Altimeter
12. Remarks (RMK)
    A. Automated, Manual and Plain Language
    B. Additive and Maintenance Data
13. Example Of METAR Report and Explanation

1. TYPE OF REPORT (BASIC)

There are two types of reports—the **METAR,** which is an aviation routine weather report and occurs hourly, and **SPECI,** which is a non-routine (special) aviation weather report. When the routine observation meets special criteria, it is still reported as a **METAR** type of report. The type of report, **METAR** or **SPECI,** will always appear as the lead element of the report. A SPECI is identified to the pilot and spoken as, "SPECIAL REPORT (last two digits of the time) OBSERVATION." A **SPECI** is taken when any of the following criteria has been observed (see Table B-1):

2. ICAO STATION IDENTIFIER (ICD)

The METAR code uses ICAO four-letter station identifiers (4ICD) that follow the type of report. In the conterminous United States, the three-letter identifier (3ICD) is prefixed with K. For example SEA (Seattle) becomes KSEA. Elsewhere, the first one or two letters of the ICD indicate in which region of the world and country (or state) the station is. Pacific locations such as Alaska, Hawaii, and the Marianas islands start with P followed by an A, H, or G, respectively. The last two letters reflect the specific reporting station ID. If the location's 3ICD begins with an A, H, or G, the P is just added to the beginning. If the location's 3ICD does not begin with an A, H, or G, the last letter is dropped and the P is added to the beginning. En Route facilities display **three letter** station IDs as the first element of a report; the K or P is **not** shown.

Table B-1. SPECI Criteria

Report Element	Criteria
Wind	A wind shift
Visibility	Certain changes in visibility which cause the weather to change flight categories (IFR, MVFR, or VFR)
RVR	Changes to above or below 2400 feet
Tornado, Funnel Cloud, Waterspout	When observed or disappears from sight (end)
Thunderstorm	Begins or ends
Precipitation	If certain types of precipitation begin, end, or change intensity
Squalls	When they occur
Ceiling	Certain changes in ceilings which cause the weather to change flight categories (IFR, MVFR, or VFR)
Sky Condition	A layer of clouds or obscuring phenomena aloft forms below 1000 feet
Volcanic Eruption	When an eruption is first noted
Aircraft Mishap	Upon notification of an aircraft mishap, unless there has been an intervening observation.
Miscellaneous	Any other meteorological situation designated by the agency, or which, in the opinion of the observer, is critical.

Examples: ANC (Anchorage, AK) becomes PANC
NOME (Nome, AK) becomes PAOM
HNL (Honolulu, HI) becomes PHNL
KOA (Keahole Point, HI) becomes PHKO
GRO (Rota Becomesland) becomes PGRO
UAM (Anderson AFB) becomes PGUA

3. DATE and TIME of REPORT (BASIC)

The date and time the observation is taken are transmitted as a six-digit date/time group appended with **Z** to denote Coordinated Universal Time (UTC). The first two digits are the date followed with two digits for hour and two digits for minutes. If a report is a correction to a previously disseminated erroneous report, the time entered on the corrected report shall be the same time used in the report being corrected. The date/time group follows the ICD.

Example: **021350Z** "One three five zero observation"

The HOST computer at En Route facilities edit out the date, only showing the four digits of the time of the observation. The time follows the 3ICD.

4. MODIFIER (As Required)

The modifier element, if used, follows the date/time element. The modifier, **AUTO**, identifies a METAR/SPECI report as an automated weather report with no human intervention. If **AUTO** is shown in the body of the report, the type of sensor equipment used at the station is encoded in the remarks section of the report. The absence of **AUTO** indicates that the report was made manually or the automated report had human augmentation/backup. An automated weather report is introduced using the phraseology; "(location name) AUTOMATED WEATHER OBSERVATION." The modifier, **COR**, identifies a corrected report that is sent out to replace an earlier report with an error.

5. WIND

The wind element is reported as a five-digit group (six digits if speed is over 99 knots) and follows the date/time or modifier element. The first three digits are the direction from which the wind is blowing in

tens of degrees referenced to true north. Directions less than 100 degrees are preceded with a zero. The next two digits are the average speed in knots, measured or estimated, or if over 99 knots, the next three digits. If the wind speed is less than one knot, the wind is reported as calm, **00000KT**. If the wind is gusty, ten knots or more between peaks and lulls, **G** is reported after the speed followed by the highest gust reported. The abbreviation, **KT**, is appended to denote the use of knots for wind speed but is **not** spoken. Other countries may use kilometers per hour or meters per second.

Examples: **13008KT** "Wind one three zero at eight"
08032G45KT "Wind zero eight zero at three two gusts four five"
00000KT "Wind calm"

VARIABLE WIND: If the wind direction is variable by 60 degrees or more and the speed is greater than 6 knots, a variable group consisting of the extremes of the wind directions separated by **V** will follow the wind group. The wind direction may also be considered variable if the wind speed is 6 knots or less and in your opinion is varying in direction (60 degree rule does not apply); this is indicated by **VRB**.

Example: **32012G22KT 280V350** "Wind three two zero at one two, gusts two two, wind variable between two eight zero and three five zero"

PEAK WIND: At facilities that have a wind recorder or at automated weather reporting systems, whenever the peak wind exceeds 25 knots, **PK WND** is included in remarks in the next report. The peak wind remark includes 3 digits for direction and 2 or 3 digits for speed followed by the time of occurrence in hours and minutes. If the hour can be inferred from the report time, only the minutes are reported.

Example: **PK WND 28045/1955** "Peak wind two eight zero at four five occurred at one niner five five"

WIND SHIFT: When a wind shift occurs, **WSHFT** is included in remarks followed by the time the wind shift began (with only minutes reported, if the hour can be inferred from the time of observation). The contraction, **FROPA**, may be entered following the time if the wind shift is the result of a frontal passage.

Example: **WSHFT 30 FROPA** "Wind shift at three zero due to frontal passage"

6. VISIBILITY

The visibility element follows the wind element. Visibility is reported in sm with a space and then fractions of sm, as needed, with **SM** appended to it. Other countries may use meters. When visibilities are less than seven miles, the restriction to visibility is shown in the weather element. The only exception to this rule is that if volcanic ash, low drifting dust, sand, or snow are observed, they are reported, even if they do **not** restrict visibility to less than 7 miles.

Example: **15SM** "Visibility one five"
2 1/2SM "Visibility two and one-half"

TOWER OR SURFACE VISIBILITY: If tower or surface visibility is less than four sm, the lesser of the two is reported in the body of the report; the greater is reported in the remarks. Example:

In the Body	In Remarks	Phraseology
3/4SM (Surface Visibility)	TWR VIS 1	"Tower visibility one"
2SM (Tower Visibility)	SFC VIS 2 ½	"Surface visibility two and one-half"

AUTOMATED VISIBILITY: Automated reporting stations will show visibility less than ¼ sm as **M1/4SM** and visibility ten or greater than ten sm as **10SM**.

Example:	**M1/4SM**	"Visibility less than one-quarter"
	10SM	"Visibility one zero"

SECOND SITE SENSORS: For automated reporting station having more than one visibility sensor, site specific visibility which is lower than the visibility shown in the body is shown in remarks.

Example: **VIS 2 RY11** "Visibility two, at Runway one one"

VARIABLE VISIBILITY: When the prevailing visibility rapidly increases or decreases by ½ sm or more, during the observation, and the average prevailing visibility is less than three sm, the visibility is variable. Variable visibility is shown in remarks with the minimum and maximum visibility values.

Example: **VIS 1V2** "Visibility variable between one and two"

SECTOR VISIBILITY: Sector visibility is shown in remarks when it differs from the prevailing and either the prevailing or sector visibility is less than three sm.

Example: **VIS N 2** "Visibility north two"

Table B-2 shows what is reported at both automated weather and manual reporting stations along with reportable values.

Table B-2. Visibility Reportable Values

	Type of Station	
Visibility	**Automated**	**Manual**
Surface	Represents 10 minutes of sensor outputs.	Visual evaluation of visibility around the horizon.
Variable	Reported when the prevailing visibility varies by ½ mile or more and the average visibility is less than 3 miles.	
Tower	Augmented.	Reported at stations with an ATCT.
Sector	**Not** reported.	Reported at all stations.
Reportable Values in Sm	M1/4 ¼ ½ ¾ 1 1 ¼ 1 ½ 1 ¾ 2 2 ½ 3 4 5 6 7 8 9 10	0 1/16 1/8 3/16 ¼ 5/16 3/8 ½ 5/8 ¾ 7/8 1 1 1/8 1 ¼ 1 3/8 1 ½ 1 5/8 1 ¾ 1 7/8 2 2 ¼ 2 ½ 2 ¾ 3 4 5 6 7 8 9 10 11 12 13 14 15, etc., in 5-mile increments

Prevailing visibility is the greatest distance that can be seen throughout at least half of the horizon circle, **not** necessarily continuous. Surface visibility is entered in column 7a, and tower visibility is entered in column 7b of the MF1M-10C form. The following visibility condition requires the issuance of a **SPECI** report:

- visibility in the body of the report decreases to less than, or if below, increases to equal or exceed:
  - 3 sm;
  - 2 sm;
  - 1 sm;
  - The lowest standard instrument approach procedure minimum as published. If none published, use ½ mile.

7. RUNWAY VISUAL RANGE (RVR)

Runway Visual Range (RVR), when reported, is in the following format: **R** identifies the group followed by the runway heading and parallel runway designator if needed, "/" and the visual range in feet (meters in other countries) followed with **FT**. The word "feet" is **not** spoken. RVR follows the visibility element. The HOST computer at En Route facilities will **not** display the RVR element.

VARIABLE RVR

When RVR varies by more than one reportable value, lowest and highest values are shown with **V** between them.

MAXIMUM / MINIMUM RANGE

When the observed RVR is above the maximum value which can be determined by the system, it should be reported as **P6000** where 6000 is the maximum value for this system. This is spoken as "more than." When the observed RVR is below the minimum value which can be determined by the system, it should be reported as **M0600** where 600 is the minimum value for this system. This is spoken as "less than." Example:

R32L/1200FT	"Runway three two left R-V-R one thousand two hundred" **or** "Runway three two left visual range one thousand two hundred"
R19/1000V2000FT	"Runway one nine R-V-R variable between one thousand and two thousand" **or** "Runway one nine visual range variable between one thousand and two thousand"
R22C/M0600FT	"Runway two two center visual range less than six hundred" **or** "Runway two two center R-V-R less than six hundred"
R27R/M1000V4000FT	"Runway two seven right R-V-R variable from less than one thousand to four thousand" **or** "Runway two seven right visual range variable from less than one thousand to four thousand"
R04/P6000FT	"Runway four R-V-R more than six thousand" **or** "Runway four visual range more than six thousand"
R08/2000VP6000FT	"Runway eight R-V-R variable from two thousand to more than six thousand" **or** "Runway eight visual range variable from two thousand to more than six thousand"

RVR shall be reported whenever the prevailing visibility is one sm or less and/or the RVR for the designated instrument runway is 6,000 feet or less.

Automated weather reporting stations with next generation RVR sensors may report up to four RVR values for up to four designated runways. Manual reporting stations may report only one RVR value for a designated runway. If RVR should be reported, but is missing, **RVRNO** will go in remarks. RVR values are entered on the MF1M-10C form in column 8.

The following RVR condition requires the issuance of a **SPECI** report:

- the highest value from the designated RVR runway decreases to less than, or if below, increases to equal or exceed 2,400 feet during the preceding 10-minutes.

- US military stations may **not** report a **SPECI** based on RVR.

8. WEATHER PHENOMENA

The weather element follows the visibility element or RVR.

> **Note:** The phraseology for the various weather phenomena contractions is as shown Table B-3 below unless otherwise addressed in the training.

Table B-3. Notation for Reporting Weather Phenomena

QUALIFIER				WEATHER PHENOMENA					
INTENSITY PROXIMITY 1		DESCRIPTOR 2		PRECIPITATION 3		OBSCURATION 4		OTHER 5	
-	LIGHT	MI	Shallow	DZ	Drizzle	BR	Mist	PO	Dust/Sand Whirls
		BC	Patches	RA	Rain	FG	Fog	SQ	Squalls
	Moderate (No Qualifier)	DR	Low Drifting	SN	Snow	FU	Smoke	FC	Funnel Cloud,
								+FC	Tornado or Waterspout
		BL	Blowing	SG	Snow Grains	DU	Dust	SS	Sandstorm
+	Heavy	SH	Showers	IC	Ice Crystals	SA	Sand	DS	Duststorm
		TS	Thunderstorm	PE	Ice Pellets	HZ	Haze		
VC	In the Vicinity	FZ	Freezing	GR	Hail (≤¼")	PY	Spray		
		PR	Partial	GS	small hail or snow (<¼")	VA	Volcanic Ash		
				UP	* Unknown Precipitation				

The weather groups shall be constructed by considering columns 1-5 in this table, in sequence; i.e., intensity, followed by descriptor, followed by weather phenomena; i.e., heavy rain showers(s) is coded as +SHRA.
*** Automated stations only.**

WEATHER BEGINS / ENDS: When weather begins or ends, the remarks will show any type of thunderstorms or precipitation beginning and ending times. Types of precipitation may be combined if beginning or ending times are the same.

Examples: **RAB20SNB20** "Rain and snow began at two zero"
TSB0159E30 "Thunderstorm began at zero one five niner, ended at three zero"

UNKNOWN PRECIPITATION: At automated weather reporting systems, precipitation of an unknown type is shown as **UP** when the precipitation discriminator cannot identify it with any precision.

Example: **UP** "Unknown precipitation"

HAILSTONE SIZE: When hailstones, **GR**, are shown in the body of a report, hailstone size (largest) is shown in remarks in ¼-inch increments and identified with the contraction **GR**. Hailstones less than ¼ inch are shown in the body of a report as **GS** and no remarks are entered indicating hailstone size.

Example: **GR 1 ¾** "Hailstones one and three-quarter inches in diameter"

9. SKY CONDITION (BASIC)

The sky condition element follows the weather element. Sky condition is reported in the following format: **Amount/Height/(Type) or Indefinite Ceiling/Height** The amount of sky cover is reported in eighths of sky cover, using the contractions in Table B-4:

Table B-4. Reportable Contractions for Sky Cover

Reportable Contractions	Meaning	Summation Amount
V V	Vertical Visibility (indefinite ceiling)	8/8
*SKC or CLR	Clear	0 or 0 below 12,000
FEW	Few	> 0 but ≤ 2/8
SCT	Scattered	3/8-4/8
BKN	Broken	5/8-7/8
OVC	Overcast	8/8
CB	Cumulonimbus	When present
TCU	Towering Cumulus	When present
***SKC** is reported at manual stations. The abbreviation, **CLR**, shall be used at automated stations when no clouds below 12,000 feet are reported.		

Note: For aviation purposes, the ceiling is the lowest broken or overcast layer aloft or vertical visibility into an obscuration. When verbalizing sky conditions, the word "ceiling" is spoken before the first broken or overcast layer aloft or as "indefinite ceiling" for ground-based obscurations. The reportable contraction, **FEW**, is spoken as, "Few clouds at (height)." No provision is made for reporting thin layers in METAR code.

10. TEMPERATURE / DEW POINT GROUP

Temperature/dew point group follows the sky conditions. Temperature/dew point is reported in a two-digit form in whole degrees Celsius separated by a solidus, "/." Temperatures below zero are prefixed with **M**. If the temperature is available but the dew point is missing, the temperature is shown followed by a solidus. If the temperature is missing, the group is omitted from the report.

Example: **15/08** "Temperature one five, dew point eight"

11. ALTIMETER

The altimeter element follows temperature/dew point group and is the last element in the body of a METAR or SPECI report. It is reported in a four-digit format representing tens, units, tenths, and hundredths of inches of mercury prefixed with **A**. The decimal point is <u>**not**</u> reported or stated. Other countries may use hectopascals.

Example: **A2995** "Altimeter two niner niner five"

NOTE: When the pressure is rising or falling rapidly at the time of observation, remarks will show **PRESRR** or **PRESFR** respectively.

12. REMARKS (RMK)

Remarks are included in all observations, when appropriate. The contraction, **RMK**, follows the altimeter in the body and precedes remarks. Time entries are shown as minutes past the hour if the time reported occurs during the same hour the observation is taken. If the hour is different, hours and minutes are shown. Location of phenomena within 5 sm of the point of observation is reported as at the station. Phenomena between 5 and 10 sm are reported in the vicinity, **VC**. Phenomena beyond 10 sm are shown as distant, **DSNT**. Direction of phenomena are indicated with the eight points of the compass. Distance remarks are in sm except for automated lightning remarks which are in nm. Movement of clouds or weather is indicated by the direction toward which the phenomenon is moving.

There are two categories of remarks which are shown in Table B-5.

Table B-5. Order of Remarks

AUTOMATED, MANUAL, and PLAIN LANGUAGE				**ADDITIVE and AUTOMATED MAINTENANCE DATA**	
1.	Volcanic Eruptions	21.	PRESFR or PRESRR	27.	Hourly Precipitation
2.	Tornado, Funnel Cloud, or Waterspout	22.	Sea-Level Pressure (SLPppp)	28.	Precipitation Amount
3.	STN Type (A01 or A02)	23.	ACFT Mishap	29.	24-Hr. Precipitation
4.	PK WND	24.	NOSPECI	30.	Snow Depth on Ground
5.	WSHFT (FROPA)	25.	SNINCR	31.	Water Equivalent of Snow
6.	TWR VIS or SFC VIS	26.	Other SIG Info	32.	Cloud Type
7.	VRB VIS			33.	Duration of Sunshine
8.	Sector VIS			34.	Hourly Temperature/Dew Point. (tenths)
9.	VIS @ 2nd Site			35.	Max. Temperature
10.	Dispatch Visual Range			36.	Min. Temperature
11.	(freq) LTG (type) (loc)			37.	24-Hr. Max./Min. Temperature
12.	Beginning/Ending of Precipitation/TSTMS			38.	Pressure Tendency
13.	TSTM Location & MVMT			39.	Sensor Status PWINO
14.	Hailstone Size (GR)				FZRANO
15.	Virga				TSNO
16.	VRB CIG Height				RVRNO
17.	Obscuration				PNO
18.	VRB Sky Condition				VISNO
19.	Significant Cloud Types				CHINO
20.	Sky @ 2nd Site			40.	Maint. Indicator ($)

A. AUTOMATED, MANUAL, AND PLAIN LANGUAGE REMARKS CATEGORY

This group of remarks may be generated from either manual or automated weather reporting stations and generally elaborate on parameters reported in the body of the report.

VOLCANIC ERUPTIONS: When first noted, the name of the volcano, latitude/longitude or approximate direction, and distance from your weather reporting station, date/time, size/description/height/movement of ash cloud, and other pertinent information are entered in remarks in plain language. Pre-eruption volcanic activity is <u>not</u> reported.

Example: **MT. ST. HELENS VOLCANO 70 MILES NE ERUPTED 181505 LARGE ASH CLOUD EXTENDING TO APPROX 30000 FEET MOVING SE**

Phraseology: **"MT. ST. HELENS VOLCANO, SEVEN ZERO MILES NORTHEAST, ERUPTED AT ONE FIVE ZERO FIVE. LARGE ASH CLOUD EXTENDING TO APPROXIMATELY THREE ZERO THOUSAND FEET, MOVING SOUTHEAST."**

TORNADO, FUNNEL CLOUD, WATERSPOUT (manual only): Whenever tornadoes, funnel clouds, or waterspouts begin, are in progress, or end, the phenomena, beginning and/or ending time, location, and movement are shown.

Example: **TORNADO B13 DSNT NE** "Tornado began one three past the hour to the distant northeast"

STATION TYPE (automated only): Shown as either **AO1** for automated weather reporting stations without a weather discriminator (precip. type), or **AO2** for automated weather reporting stations with a weather discriminator (precip. type).

PEAK WIND: Whenever the peak wind exceeds 25 knots, **PK WND** is included in the remarks in the next report with three digits for direction and two or three digits for speed followed by time in hours and minutes of occurrence (with only the minutes reported if the hour can be inferred from the report time).

Example: **PK WND 28045/1955** "Peak wind two eight zero at four five occurred at one niner five five"

WIND SHIFT: When a wind shift occurs, **WSHFT** is included in remarks followed by the time the wind shift began (with only minute reported, if the hour can be inferred from the time of observation). The contraction, **FROPA**, may be entered following the time if the wind shift is the result of a frontal passage.

Example: **WSHFT 45** "Wind shift at four five minutes after the hour"

TOWER OR SURFACE VISIBILITY: If either tower or surface visibility is less than four sm, the lesser of the two is reported in the body of the report; the greater is reported in the remarks.

Example: (In the body) -- **3/4SM** (In remarks) -- **TWR VIS 1** "Tower visibility one"

VARIABLE PREVAILING VISIBILITY: When the prevailing visibility rapidly increases or decreases by ½ sm or more, during the observation, and the average prevailing visibility is less than three sm, the visibility is variable. Variable visibility is shown in remarks with the minimum and maximum visibility values.

Example: **VIS 1V2** "Visibility variable between one and two"

SECTOR VISIBILITY: Sector visibility is shown in remarks when it differs from the prevailing visibility by one or more reportable values and either the prevailing or sector visibility is less than three miles.

Example: **VIS N 2** "Visibility north two"

VISIBILITY AT SECOND SITE (automated only): For automated reporting station having more than one visibility sensor, site specific visibility which is lower than the visibility shown in the body is shown in remarks.

Example: **VIS 2 RY11** "Visibility two, at Runway one one"

DISPATCH VISUAL RANGE (DVR): The dispatch visual range, **DVR**, is a value derived from the automated surface observation system visibility sensor. The DVR is shown in remarks when the means of reporting RVR is not available. The coding standards used to report RVR values in the body of a report are the same for reporting DVR values in remarks. Only one DVR value, for the designated runway, is reported.

Example: **DVR/1200FT** "Dispatch visual range one thousand two hundred"

LIGHTNING: When lightning is seen by the weather observer, it is included in remarks. The frequency of occurrence, type of lightning when observed, and the location is indicated. The frequency and type of lightning contractions are listed below. The location is determined in reference to point of observation.

Frequency of Lightning

OCNL "Occasional" (less than 1 flash/minute)

FRQ "Frequent" (about 1 to 6 flashes/minute)

CONS "Continuous" (more than 6 flashes/minute)

Type of Lightning

CG "Cloud-to-ground"

IC "In-cloud"

CC "Cloud-to-cloud"

CA "Cloud-to-air"

Examples:	**OCNL LTGICCG NW**	"Occasional lightning in cloud and cloud to ground northwest"
	FRQ LTG VC	"Frequent lightning in the vicinity of the station"

Lightning detected by an automated weather reporting system:

- > 5 nm of Airport Location Point (ALP) is reported as **TS** in the body of the report, with no remark.
- 5 to 10 nm of ALP is reported as **VCTS** in the body of the report, with no remark.
- 10 to 30 nm of ALP is reported in remarks as **LTG DSNT,** followed by the direction from ALP.

BEGINNING AND/OR ENDING TIMES FOR PRECIPITATION: When precipitation begins or ends, remarks will show the type of precipitation as well as the beginning and/or ending time(s) of occurrence. Intensity qualifiers are <u>not</u> shown. Only the minutes are required if the hour can be inferred from the report time. Types of precipitation may be combined if beginning or ending at the same time. These remarks are <u>not</u> required in SPECI reports but are shown in the next METAR report.

Example: **RABSNB20E55** "Rain and snow began at two zero, ended at five five"

BEGINNING AND/OR ENDING TIMES FOR THUNDERSTORMS: When thunderstorms begin or end, remarks will show the thunderstorm as well as the beginning and/or ending time(s) of occurrence. Only the minutes are required if the hour can be inferred from the report time. These remarks are required in SPECI reports and will also be shown in the next METAR report.

Example: **TSB05E40** "Thunderstorm began at zero five, ended at four zero"

THUNDERSTORM LOCATION: Thunderstorm(s) location and movement is shown in remarks as **TS** followed by location and movement.

Example: **TS OHD MOV N** "Thunderstorm overhead, moving north"

HAILSTONE SIZE: The size of the largest hailstones, in ¼-inch increments, is shown in remarks preceded with the contraction for hail, **GR**. Small hail or snow pellets, **GS**, are encoded in the body of the report, with no size remark.

Example: **GR ¾** "Hailstones three-quarter inch in diameter"

VIRGA: When precipitation is observed but <u>**not**</u> reaching the ground, **VIRGA** is shown in remarks. The direction from the station may also be reported.

Example: **VIRGA SW** "Virga southwest"

VARIABLE CEILING: Whenever the ceiling is below 3,000 feet and is variable, the remark, **CIG,** is shown followed with the lowest and highest ceiling heights.

Example: **CIG 005V010** "Ceiling variable between five hundred and one thousand"

OBSCURATIONS: When an obscuration (surface or aloft) is observed, the obscuring phenomenon followed by the amount of obscuration, **FEW**, **SCT**, or **BKN**, followed by three zeros or the layer height is shown in remarks.

Examples: **VA SCT000** "Volcanic ash obscuring three- to four-eighths of the sky"

FU BKN020 "Broken layer of smoke aloft, based at two thousand"

VARIABLE SKY CONDITION: When a layer that is 3,000 feet or less is varying in sky cover, remarks will show the variability range. If there is more than one cloud layer, the variable layer is identified by including the layer height.

Example: **SCT V BKN** "Scattered variable broken"

BKN025 V OVC "Two thousand five hundred broken variable overcast"

SIGNIFICANT CLOUDS: When significant clouds are observed, they are shown in remarks. The following cloud types are shown:

> ***Cumulonimbus,*** **CB**, or ***Cumulonimbus Mammatus,*** **CBMAM**, direction from the station, and direction of movement (if known). If the cloud is beyond 10 miles from the airport, **DSNT** will indicate distance.
>
> Example: **CB W MOV E** "Cumulonimbus west moving east"
>
> **CBMAM DSNT S** "Cumulonimbus mammatus distant south"

Towering cumulus, **TCU**, and direction from the station.

Example:	**TCU OHD**	"Towering cumulus overhead"
	TCU W	"Towering cumulus west"

Altocumulus castellanus, **ACC**, standing lenticular (stratocumulus, **SCSL**, altocumulus, **ACSL**, or cirrocumulus, **CCSL**), or rotor clouds, will show a remark describing cloud and its direction from station.

Example:	**ACC W**	"Altocumulus castellanus west"
	ACSL S - SW	"Standing lenticular altocumulus south through southwest"
	APRNT ROTOR CLD S	"Apparent rotor cloud south"
	CCSL OVR MT E	"Standing lenticular cirrocumulus over the mountain(s) east"

CEILING AT SECOND SITE (automated only): When an automated station uses meteorological discontinuity sensors, remarks is shown to identify site specific cloud heights. The remark is in the format **CIG <height> <location>**, where the height measured is followed by the secondary location.

Example: **CIG 020 RY11** "Ceiling two thousand at runway one one"

PRESSURE RISING/FALLING RAPIDLY: At designated stations, when the pressure is rising or falling at a rate of at least 0.06 inch per hour and the pressure change totals 0.02 or more at the time of observation, remarks will show **PRESRR** or **PRESFR** respectively.

SEA-LEVEL PRESSURE: At designated stations that report sea-level pressure, this remark begins with **SLP** and is coded using tens, units, and tenths of sea-level pressure in hectopascals (same as millibars). If no sea-level pressure is available, it is shown as **SLPNO**. **SLPNO** is <u>not</u> entered in SPECI reports taken at manual stations

Example: **SLP132** "Sea-level pressure one zero one three point two hectopascals"

AIRCRAFT MISHAP: If a report is taken to document weather conditions when notified of an aircraft mishap, the remark, **(ACFT MSHP)**, including the parenthesis, is included in the report. The remark is **<u>not</u>** transmitted.

NO SPECI AVAILABLE: At manual weather observing stations that do **<u>not</u>** take SPECI reports, **NOSPECI** is shown in remarks of all **METAR** reports.

SNOW INCREASING RAPIDLY: Reported at designated stations whenever the snow depth increases by 1 inch or more in the past hour. The remark, **SNINCR**, is followed with the **depth increase** in the past hour, a solidus, /, and the **total snow depth** on the ground at the time of the report.

Example: **SNINCR 2/10** "Snow increase two inches during past hour total depth on the ground of ten inches"

OTHER SIGNIFICANT INFORMATION: Operationally significant information such as fog dispersal operations, runway conditions, or first and last reports may be added to remarks here.

B. ADDITIVE AND MAINTENANCE DATA REMARKS CATEGORY

Additive data groups are only reported at designated stations. The maintenance data groups are only reported from automated weather reporting stations. Most remarks in this category are discussed in Remarks Advanced Training, however, the last two remarks in this category is covered here.

SENSOR STATUS INDICATORS: If the RVR element in the body should be reported but is missing, **RVRNO** is shown here.

Example: **RVRNO** "Runway visual range information **not** available"

If any of the following sensors is located at automated weather reporting station and **not** working, the appropriate remark will appear:

Example:	**PWINO**	"Present weather identifier **not** available"
	PNO	"Precipitation amount **not** available"
	FZRANO	"Freezing rain information indicator **not** available"
	TSNO	"Lightning information **not** available"
	VISNO	"Visibility sensor information **not** available"
	CHINO	"Cloud height indicator information **not** available"

Note: **VISNO** (runway) and **CHINO** (runway) may be used at secondary site sensors.

Example:	**VISNO RY06**	"Visibility sensor at runway six information **not** available"
	CHINO RY11	"Cloud height indicator information at runway one one **not** available"

MAINTENANCE INDICATOR: A maintenance indicator sign, "**$**," is included when an automated weather reporting system detects that maintenance is needed on the system.

13. Example Of METAR Report and Explanation

METAR KMKL 021250Z 33018KT 290V360 1/2SM R31/2600FT +SN BLSN FG VV008 00/M03 A2991 RMK RAESNB42 SLPNO T00111032

METAR	aviation routine weather report
KMKL	Jackson, TN
021250Z	date 02, time 1250 UTC
33018KT	wind 330 at 18 knots
290V360	wind direction variable between 290 and 360 degrees
1/2SM	visibility one-half
R31/2600FT	runway 31, RVR 2600
+SN	heavy snow
BLSN FG	blowing snow and fog
VV008	indefinite ceiling 800
00/M03	temperature zero, dew point minus 3
A2991	altimeter 2991

RMK	remarks
RAESNB42	rain ended at four two, snow began at four two
SLPNO	sea-level pressure not available
T00111032	temperature 0.1°C, dew point -3.2°C

The following example shows the phraseology used to relay this report to a pilot. Optional phrases or words are shown in parentheses.

"Jackson (Tennessee), (one two five zero observation), wind three three zero at one eight, wind variable between two niner zero and three six zero, visibility one-half, runway three one RVR, two thousand six hundred, heavy snow, blowing snow, fog, indefinite ceiling eight hundred, temperature zero, dew point minus three, altimeter two niner niner one"

En Route controllers may see the above report displayed on the CRD in the following abbreviated format.

MKL 1250 M 33018KT 290V360 1/2SM +SN BLSN FG VV008 00/M03 A2991 RMK RAESNB42 SLPNO T0011103

APPENDIX C

OPERATOR EVALUATION QUESTIONNAIRE

A questionnaire asked controllers to assess the general utility of the radar system for AT operations. Results are given on p. 4-41.

Areas of questions on the radar system interface included: Auditory Alerts, Data Entry Devices, Display Screens and Controls, Ergonomics and Workload, Functional Capabilities, and Summary Questions. The questionnaire is attached below.

Introduction

Air traffic controllers assessing radar performance are also asked to briefly evaluate:

- the training session, and
- the system's operator interface.

Please give brief but thoughtful answers in the sections that follow.
Try to give examples and explanations wherever possible.

Points to consider when evaluating the radar interface are:
Are messages easy to understand? Are controls easy to use? Does it give you a "complete picture" surface awareness? Does the system respond quickly and accurately? Do you see all information you need on the display? Is it easy for you to keep track of your actions and status? Are alerts clear in meaning and prominently displayed? Do you know how to respond to them?

As you make your assessment, think of five human factors "c" words:

Clarity
Concentration
Communication
Consistency
Control

If you need more space, please write on the back of the same page, and identify your response by the appropriate number or letter.

Thank you for your participation and response in this evaluation. Your answers, observations and suggestions may influence the final design of this and other surface surveillance radar systems.

> ***NOTE:** Please make your evaluations of radar operations during low-visibility conditions whenever possible.*

Training Evaluation

Please evaluate the following aspects of your **training session** in radar system use. Rate the categories numerically on a scale of 1-5 **and** add your personal observations. Note that this evaluation is of the **presentation and materials**, not of the system itself.

Numerical Ratings

1. *Unsatisfactory:* inadequate explanation and poor definition of radar use for AT operations.
2. *Fair:* some areas covered, but not sufficient preparation to use system for most AT operations.
3. *Good:* adequate presentation overall, but certain areas need significant improvement.
4. *Very Good:* most scenarios/operations clearly covered, only details require more focus and definition.
5. *Excellent:* thorough, all aspects clearly presented, very positive opinion, inspired confidence.

Your Ratings/Observations

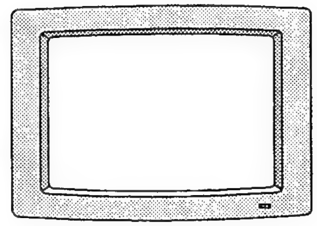
	1 - 5	Observations
A: Coverage of operations: Were all aspects of hands-on radar control for AT covered adequately?		
B: Verbal presentation: Was instructor organized, clear and thorough explaining? Answering questions?		
C: Organization and completeness of user manual: Did manual support and clarify all controls and functions?		
D: Improvements needed: Are there topics which were not covered well or remain unclear?		
E: Confidence factor: Did you learn all you need to know to run and test radar with confidence?		

Further Comments, Suggestions, Questions

Operator Evaluation of Radar Interface

Auditory Alerts (Error Messages)

1. Did you **[see / hear / both see and hear]** a system error alert? [circle one]
2. Was the beep easy to recognize from across the cab? [Y/N]
3. Was the flashing screen easy to see from across the cab? [Y/N]
4. Where did the error message window appear? ____________________________



5. Did the message tell you what caused the error? [Y/N]
6. What caused the user entry error? ______________________________________.
   - Data Entry, Capacity, Blank Data Field, Illegal Value.
   - None of the above. [write in:_____________________]
7. Were you able to correct the error? [Y/N]
8. If yes, did you do so by correcting the error or simply disabling the alert? [circle]
9. Were you able to do so quickly, without interrupting normal AT operations? [Y/N]
10. If not, why not? ____
11. Was the error message accompanied by another alert? [Y/N]
12. Did the error affect system functionality? [Y/N; if Y, explain] ___________________
    ____

Data Entry Devices

Please answer these questions Never/Sometimes/Always; add your comments.

1. Are data entry devices easy to use? [circle one] **N S A**

2. Are dialog boxes, menus, and displays clear and easy to use? **N S A**

3. Is it easy to keep track of what you're doing with the mouse? **N S A**

4. Can you select the range scale you want? **N S A**

5. Are there problems creating a runway/taxiway map? **N S A**

6. Can you identify false targets and their cause? **N S A**

7. Do hot keys and toggle buttons function properly? **N S A**

8. Do Function ("Hot") Keys perform accurately and quickly? **N S A**

9. Does adjusting IR remove interference? **N S A**

Use as much space as you need; if you continue answers on other side, please number them.

Display Screen & Controls

Please answer these questions Never/Sometimes/Always; add your comments.

1. Are controls sequenced in an order that is easy to follow? [circle one] **N S A**

2. Are screen labels and boxes well-positioned? **N S A**

3. Are screen labels and commands clear? **N S A**

4. Is the text easy to read? **N S A**

5. Are the screen areas laid out in the clearest possible way? **N S A**

6. Is the hi-brite monitor readable in both dim light and direct sunlight? **N S A**

7. Can you distinguish all the colors in direct sunlight? **N S A**

Use as much space as you need; if you continue comments overleaf, please number them.

Ergonomics & Work Load

1. Does the computer offer information and advice on conflict resolution?
____
____

2. Do you have complete, accurate awareness of surface situation?
____
____

3. Are controls positioned well for your use?
____
____

Functional Capabilities

Please give a utility rating (1-5) and brief comment of the following radar functions:

Function	Rating	Comment
1. Scan to Scan Integration:	_____	_____________________
2. Gain Setting:	_____	_____________________
3. SEA Setting:	_____	_____________________
4. RAIN Setting:	_____	_____________________
5. FTC Setting:	_____	_____________________
6. Overall Adjustment:	_____	_____________________
7. Radar Degradation (30'):	_____	_____________________
8. Range Operation:	_____	_____________________
9. Data Brilliance Operation:	_____	_____________________
10. Offset Operation:	_____	_____________________
11. Map Building & Rotation:	_____	_____________________

Summary Questions

Please give numerical ratings and add your own observations.
Use the scale: *(1) Unsatisfactory, (2) Fair, (3) Good, (4) Very Good, (5) Excellent.*

1. Are all labels and terms clear and not confusable? rating:_______

2. Can you get the views you want of the airport surface? rating:_______

3. Are the controls easy to use? rating:_______

4. Are screen prompts clear, brief, and not confusable? rating:_______

5. Does the system respond quickly to your commands? rating:_______

6. What--if any--vital information is missing from the display?

7. Can you suggest changes to the display or controls to make your job easier?

8. Does the display make clear how to respond to error messages?

9. Do error messages make clear how system failure may limit AT operations?

Use as much space as you need; if you continue answers on the back, please number them.

APPENDIX D

RSEC CALCULATION

NOTE: The Radio Spectrum Engineering Criteria (RSEC) calculation is used as reference to the RSEC functional test (Section 3.5.6).

A radio frequency spectrum standard is one of the RSEC that bounds the spectrum-related parameters and characteristics of a radio system in order to manage the Radio Frequency Spectrum. The wide application of radar for various functions makes large demands on the electromagnetic spectrum, and requires the application of effective frequency management measures for the equipment and systems involved. RSEC are specified for certain equipment characteristics to establish and ensure that an acceptable degree of electromagnetic compatibility is maintained among radar systems, and between such systems and those of other radio services sharing the frequency spectrum.

According to the *Manual of Regulations and Procedures for Radio Frequency Management* (MRFM, to which all references in this appendix are made), the theoretical RSEC value for Phase II Radar at MKE is: 358 MHz.

The RSEC value for the Phase II radar was found by making the following calculations, found in MRFM, Section 5.

- Determine characteristics of the radar system.

  The Phase I radar parameters (used to cross-reference manual tables) are:

Frequency:	9.375 GHz
Peak power output:	25 kW
Rise time (t_r):	10 nsec = 0.01 µsec
Pulse width (t):	45 nsec = 0.45 µsec.

  NOTE: Figure D-1 shows rise time and pulse width measurements. Nominal flat top level delineates the pulse peak level with "bumps" smoothed out. Arrows indicate pulse width and rise time.

- Look up levels of unwanted emissions and frequency tolerances in the Table of Frequency Tolerances and Unwanted Emissions (MRFM, 5-2 - 5-4) using the correct frequency band.

  For MKE, the range is 4000 MHz to 10.5 GHz.
  The sub category is radar, in the Radionavigation Stations section.
  The level of unwanted emissions is category F, thus the tolerances are determined using MRFM, Section 5.3.

- Look up Applicable Criteria based on the Radar Description in the table, MRFM, 5-7.

  The Phase I radar group is group B, radars having a rated peak power of more than 1 kW but not more than 100 kW and operating between 2900 MHz and 40 GHz. This group was used because of the frequency, and the peak power being within the specifications. This put the radar system in Criteria B of applicable criteria.

- Look up calculations for Criteria B in MRFM, Section 5.3.1. Since the Phase II radar is a non-FM pulse radar system, procured after October 1, 1986, when the criteria were established, the equation to use is:

$$B(-40\text{ dB}) = (7.6 / \sqrt{t_r t}) \text{ or } (64 / t)$$
(whichever is less)

t_r is rise time, and t is pulse width, both given in μsec, not nsec.

$$B\ (-40\text{ dB}) = 7.6 / \sqrt{(.00045)} = \mathbf{358}\text{ MHz}$$

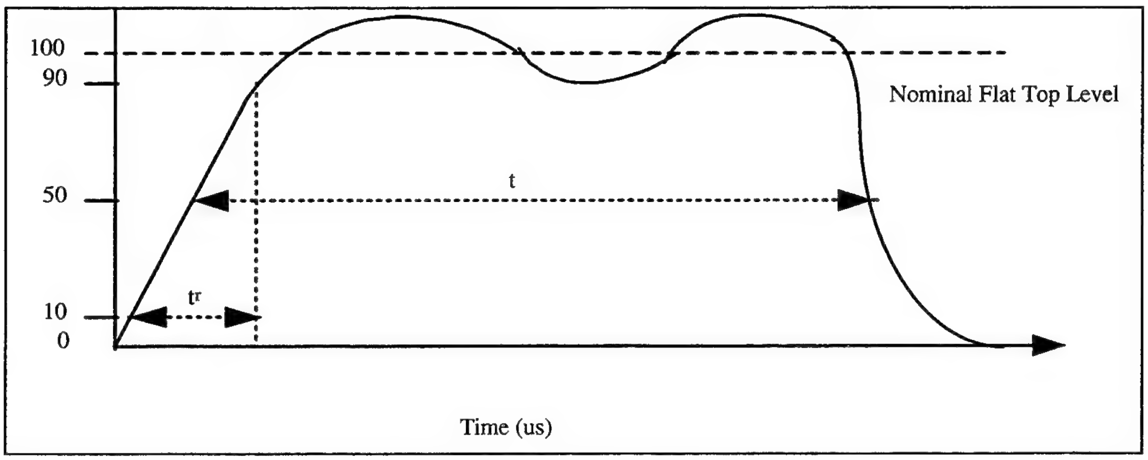


Figure D-1. Pulse Measurement.

APPENDIX E

SPARES LIST

The MKE ASDE system came with a set of spare parts, catalogued below with their Raytheon part numbers. Each item is supplied in one unit; except #29 (5 VDC Power Supply) of which there are two. Each item on the list has been grouped by its priority:

Priority 1 items, critical to system operation, are stored on-site (in the equipment room). These custom-designed parts or ASDE power supplies are available in limited quantities, and therefore require long lead-times for ordering.

Priority 2 - Standard production items maintained in Raytheon inventory.

Priority 3 - Standard production items maintained in Raytheon inventory.

Questions regarding current price, availability and ordering should be directed by phone to Raytheon Govt. Programs at 603-624-4718 or by e-mail to <john_p_higgins@raytheon.com>. Credit card may be place via FAX 603-634-4719.

Priority 1

ITEM #	DESCRIPTION	PART #
1	Rotary Joint	1032582-2
4	Drive Belts	1032581-3
6	Modulator	G623250-2
9	Power Supply	G263697-1
12	Magnetron	290-7276P1
29*	5 VDC Power Supply*	G260211-1
30	12 VDC Power Supply	G260205-1
31	Isolation Rectifier (I/R)	G259784-1
34	Switch Matrix Power Supply	G623897-1
40	Low Voltage Power Supply	G622942-13
41	High Voltage Power Supply	G622942-14
43	Focus Power Supply	G622942-16
46	Extender PCB Kit	M28101

*2 of Item 29 required.

Priority 2

ITEM #	DESCRIPTION	PART #
5	Controller Assy	G262253-1
7	IF Amplifier	G623045-3
8	Sense/AFC PCB	G623235-1
13	Ant Control Relay	G623525-1
14	User Interface	G262127-2
15	Synthetic Memory Module (SMM)	G262216-1
16	Radar Scan Converter (RSC)	G260742-1
17	Video Processor "B" (VPB)	G260150-1
18	Video Processor "A" (VPA)	G260694-3
19	External Interface Unit (EIU)	G260689-2
20	ASDE Interswitch (AIS)	G261787-1
21	Integrated Memory Module (IMM)	G261741-4
22	TDE Display Interface "B" (DIB)	G260697-3
23	Display Interface "A" (DIA)	G260732-3
24	ASDE Optional Processor (AOP)	G623241-1
25	ASDE Navigation Processor (ANP)	G623240-1
26	ASDE Radar Processor (ARP)	G623239-1
27	Processor Common Memory (PCM)	G260738-2
28	Voltage Supervisor	G623227-1
33	Switch Matrix PCB Assy	G623334-1
35	Touch Panel (Touch Pad)	G623898-1
36	Trackball	G623878-1
37	Junction Box PCB	G623444-1

Priority 3

ITEM #	DESCRIPTION	PART #
2	Drive Motor	G623859-1
3	Optical Encoder	G623255-1
10	Isolator	G623751-1
11	TR Limiter	G623752-1
32	Switch Panel Module PCB Assy	G623504-1
38	Vertical Deflection PCB	G622942-11
39	Video Drive PCB	G622942-12
42	Cathode Ray Tube	G622942-15
44	Horizontal Deflections PCB	G622942-17
45	Astigmator Drive PCB	G622942-18

APPENDIX F

ANCILLARY DOCUMENTS

ASDE
RADAR SYSTEM
CERTIFICATION SHEET

DATE: 12/6/96 LOCATION: MILWAUKEE, WI

DATE INSTALLATION COMPLETED: 12/6/96

INSTALLING ACTIVITY: TAMSCO, BELTSVILLE, MD.

RAYTHEON FIELD ENGINEER: VINCENT HORAN

ASDE
RADAR SYSTEM
PEDESTAL CHECKLIST

Pedestal Serial # ~~003 (18CPX-12)~~ ~~00~~ H 08401
Array Serial # 003 (18CPX-12)

1) Array properly mounted using supplied hardware.	X
2) Unrestricted beam pattern (note obstruction areas below).	X
3) Gear reducer plug shipping cap removed.	X
4) Pedestal bonding strap installed.	X
5) Waveguide window installed. (INSIDE PENT HOUSE)	X
6) Waveguide flex installed at pedestal. (CUSTOMER SUPPLIED)	X
7) Waveguide properly installed and supported.	X
8) Cabling:	
a) Properly terminated and crimped.	X
b) Shields, drains and unused conductors grounded.	X
9) Pedestal location TOP OF CAB AT CONTROL TOWER	
10) Pedestal height above ground.	62 Meters
11) Pedestal motor voltage.	208 VAC
a) L1 - L2	207 VAC
b) L2 - L3	205 VAC
c) L1 - L3	208 VAC
12) Pedestal shock mounts properly installed.	O

NOTE: AUTRONICA SLOW START WAS MODIFIED FOR 220 VAC 3Ø - HAD BEEN 440 VAC 3Ø
GET NOTES FROM BEN.

ASDE
RADAR SYSTEM
VIDEO PROCESSOR CABINET
MTR **CHECKLIST**

MTR
VIDEO PROCESSOR CABINET
SERIAL # 540475

1. Cabinet securely fastened to deck. X
2. Cabinet properly bonded to ground. X
3. Service access to cabinet. X
4. Input voltage to Cabinet ~~from UPS.~~ 118 VAC 60 HZ
5. Switch Panel Logic Power Supply voltages.
    a) 5 VDC 4.98 VDC
    b) +12 VDC +11.9 VDC
    c) -12 VDC -8.07 VDC
6. Matrix Switch Panel fully operational. X

ASDE RADAR SYSTEM
DISPLAY MONITOR
CHECKLIST

PROCESSOR CABINET MONITOR SERIAL # 17960008

1. Input voltage	115 VAC
2. TP2 (24 VDC)	____ VDC
3. TP3 (-24 VDC)	____ VDC
4. TP4 (15 VDC)	____ VDC
5. TP5 (-15 VDC)	____ VDC
6. TP6 (5 VDC)	____ VDC
7. TP7	____ VDC
8. TP11	____ VDC
9. Perform necessary video display alignment.	X
10. Junction Box.	
a) Interconnecting cable properly terminated.	X
b) Interconnecting cables properly clamped.	X
11. Touch Panel.	
a) Input voltage.	115 VAC
b) Self-test okay.	X
c) Check for proper operation of all controls.	X
12. Trackball Assembly.	
a) Check for proper operation.	X

TOUCH PANEL TOO BRIGHT

ASDE
RADAR SYSTEM
DISPLAY PROCESSOR
CHECKLIST

~~UPPE~~R DISPLAY PROCESSOR

1. Upper 5 VDC Power Supply 5.05 VDC
2. Lower 5 VDC Power Supply 5.05 VDC
3. +12 VDC Power Supply +11.9 VDC
4. -12 VDC Power Supply -12.1 VDC
5. Complete Display Processor alignment. ____
6. Display Processor data entries:
   - 3.1 Transceiver 1.1 / ~~2.1~~
   - Antenna height 63 METERS
   - PMU (not used)
   - Model ~~5~~ 6 (ASDE X)
   - Transmission line length 15 METERS
   - Front end STC (point 1) ~~28~~ 12
   - Front end STC (point 2) ~~16~~ 8
   - Front end STC (point 3) point 4 = 0 ~~4~~ 4 0
   - Antenna latitude N 42:56:868
   - Antenna longitude W 87:54:380
   - 4. Calibration: Direct entry
   - Antenna offset 306.0
   - Zero range 2.39
   - 6.2 View up orientation 090
   - 6.3 Custom range scales

1 0.25	6 1.75
2 0.75	7 2.00
3 1.00	8 2.50
4 1.25	9 3.00
5 1.50	10 9.00

   - 7.1 Console mode NORMAL
   - 7.2 Number of consoles (1 SRD-15 DISPLAY ON MAINTENANCE POSITION) 1
   - 7.3 Set console identifier A
7. Software levels:
   - a) ARP Processor V 3.1.0 ASO
   - b) ANP Processor V 3.1.0 ASO
   - c) AOP Processor V3.1.0 ASO

NOISE LEVEL =

ASDE
RADAR SYSTEM
MTR CHECKLIST

MTR A
MTR SERIAL NUMBER NONE

1. Perform a complete MTR alignment to include:
   a) High Voltage Power Supply. X
   b) Forward transmitter power output. X
   c) Coarse tune level adjustment. X
   d) Fine tune level adjustment. X
   e) STC adjustment. X
   f) Video level adjustment (+3.5 volt peak video on the bottom of R47 on the Controller PCB). X
   g) Adjust Data level (-2.5 volts at J14 Pin 4 on the Controller PCB). 2.5
   h) Minimum discernible signal. 0
   I) VSWR X
2. Voltage measurements:
   a) Line voltage input. 118 VAC
   b) 800 VDC High Voltage 800
   c) +15 VDC 15.1
   d) -15 VDC -15.4 + 24.2 VDC
   e) 9 VDC +9.1
   f) 5 VDC +5.1
3. Peak power output in KW (average power + Duty Cycle factor). 25 KW
4. VSWR
   a) Forward power in Dbm 37.5 Dbm
   b) Reflected power in Dbm 21.5 Dbm

   VSWR = a -b = 16 Dbm
5. Insertion line loss.
   a) Average power at MTR ______Dbm
   b) Average power at Pedestal ______Dbm

   c) Insertion loss = a - b = ______Db
6. Minimum discernable signal (MDS). ______Dbm

(1) BAD VSWR IN ELLIPTICAL RUN/CONNECTORS

AUTHORIZATION NUMBER
AGL-96-3720

UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

FACILITY TRANSMITTING AUTHORIZATION

In accordance with authority granted the Federal Aviation Administration by the National Telecommunications & Information Administration through the Interdepartmental Radio Advisory Committee, this Authorization is issued for the operation of this facility.

FACILITY: MILWAUKEE, WI

COORDINATES: 42°56'52"N 087°54'23"W

FREQUENCY	FAC. TYPE	MAX. POWER	CLASS	TYPE OF SERVICE	COST CENTER	IDENT	FAA SERIAL	MISCELLANEOUS REMARKS
9375.00 MHz	ASDE	22.0 kW	XR			MKE	960046	PRR=3.63 kHz

Note: This Frequency Transmitting Authorization is to support the development of a X-band ASDE radar. This assignment is on a non-interference basis to operational systems and must immediatly cease operations when instructed to do so by the Great Lakes Region Frequency Management Office or the FAA Spectrum Policy and Management Program. Use of this frequency for development purposes does not imply that operational X-band ASDE radars can use this frequency or frequencies in this area of the X-band. This Frequency Transmitting Authorization expires at midnight December 31 1997.

23 February 1996	Great Lakes		1 of 1
EFFECTIVE DATE	FAA REGION	FREQUENCY MANAGEMENT OFFICER	PAGE

DO NOT REMOVE CARBONS

Form Approved OMB No. 2120-0001

US Department of Transportation
Federal Aviation Administration

NOTICE OF PROPOSED CONSTRUCTION OR ALTERATION

Aeronautical Study Number: 95 AGL 1263 -NRA

1. Nature of Proposal

A. Type
- [x] New Construction
- [ ] Alteration

B. Class
- [ ] Permanent
- [x] Temporary (Duration 2 months)

C. Work Schedule Dates
Beginning 11/15/95
End 12/31/95

3A. Name and address of individual, company, corporation, etc. proposing the construction or alteration. (Number, Street, City, State and Zip Code)

( ) ________
area code Telephone Number

TO
AND-410
Rick Castaldo
800 Independence Avenue SW
Washington, D. C. 20591

B. Name, address and telephone number of proponent's representative if different than 3 above.

Vincent Capezzuto
414-747-5500

2. Complete Description of Structure

A Include effective radiated power and assigned frequency of all existing, proposed or modified AM, FM, or TV broadcast stations utilizing this structure

B Include size and configuration of power transmission lines and their supporting towers in the vicinity of FAA facilities and public airports

C Include information showing site orientation, dimensions, and construction materials of the proposed structure

Location of points A, B, C, D based on the GPS coordinates of the Runway 1L Inner Marker and derived using mathematical calculations.
Coordinates based on Mag. Var. 1.5 W

A 42-55-46.120 87-53-56.988
B 42-55-46.121 87-53-58.332
C 42-55-47.108 87-53-58.331
D 42-55-47.108 87-53-56.987

(if more space is required, continue on a separate sheet.)

4. Location of Structure

A. Coordinates (To nearest second)	B. Nearest City, Town and State	C. Name of nearest airport, heliport, flightpark, or seaplane base
	Milwaukee, Wis.	on airport property
Latitude: see below	(1) Distance to 4B: Miles	(1) Distance from structure to nearest point of nearest runway
Longitude: see below	(2) Direction to 4B	(2) Direction from structure to airport: on airport property south of Rwy 1L

5. Height and Elevation (Complete to the nearest foot)

A. Elevation of site above mean sea level	706 ~~USGS~~
B. Height of Structure including all appurtenances and lighting (if any) above ground, or water if so situated	6
C. Overall height above mean sea level (A + B)	712

D. Description of location of site with respect to highways, streets, airports, prominent terrain features, existing structures, etc. Attach a U.S. Geological Survey quadrangle map or equivalent showing the relationship of construction site to nearest airport(s). (if more space is required, continue on a separate sheet of paper and attach to this notice.)

An L shaped arrangement of reflectors (temporary) on 6 foot poles that will be established within the box designated by points A, B, C, D. See attached portion of "Airport Obstruction Chart" (OC 262), 11th edition, for coordinates.

Notice is required by Part 77 of the Federal Aviation Regulations (14 C.F.R. Part 77) pursuant to Section 1101 of the Federal Aviation Act of 1958, as amended (49 U.S.C. 1101). Persons who knowingly and willingly violate the Notice requirements of Part 77 are subject to a fine (criminal penalty) of not more than $500 for the first offense and not more than $2,000 for subsequent offenses, pursuant to Section 902(a) of the Federal Aviation Act of 1958, as amended (49 U.S.C. 1472(a)).

I HEREBY CERTIFY that all of the above statements made by me are true, complete, and correct to the best of my knowledge. In addition, I agree to obstruction mark and/or light the structure in accordance with established marking & lighting standards if necessary.

Date	Typed Name/Title of Person Filing Notice	Signature
10/17/95	Vincent Capezzuto	Vincent Capezzuto

FOR FAA USE ONLY — *FAA will either return this form or issue a separate acknowledgement.*

The Proposal:

- [ ] Does not require a notice to FAA.
- [ ] Is not identified as an obstruction under any standard of FAR, Part 77, Subpart C, and would not be a hazard to air navigation.
- [ ] Is identified as an obstruction under the standards of FAR, Part 77, Subpart C, but would not be a hazard to air navigation.
- [ ] Should be obstruction [ ] MARKED, [ ] lighted per FAA Advisory Circular 70/7460-1; Chapter(s) ________
- [ ] Obstruction marking and lighting are not necessary.

Supplemental Notice of Construction FAA Form 7460-2 is required any time the project is abandoned, or

- [ ] At least 48 hours before the start of construction.
- [ ] Within five days after the construction reaches its greatest height.

This determination expires on ________ unless:
(a) extended, revised or terminated by the issuing office;
(b) the construction is subject to the licensing authority of the Federal Communications Commission and an application for a construction permit is made to the FCC on or before the above expiration date. In such case the determination expires on the date prescribed by the FCC for completion of construction, or on the date the FCC denies the application.

NOTE: Request for extension of the effective period of this determination must be postmarked or delivered to the issuing office at least 15 days prior to the expiration date.

If the structure is subject to the licensing authority of the FCC, a copy of this determination will be sent to that Agency.

Remarks:

Issued in	Signature	Date

FAA Form 7460-1 (8-85)

DO NOT REMOVE CARBONS

APPENDIX G

GLOSSARY

Blanking	Shadowing of portions of antenna aperture by structures, causing blind sectors.
Blind Sector	Area of antenna sweep completely obstructed by an object (building, etc.), cutting off the radar beam; results when subtended angle of shadow > 5°.
Breakup	Radar image breaks into several parts traveling on same vector.
Clutter	Unwanted radar echoes (caused by surface irregularities, rain and other precipitation, insects, etc.) which appear as background "noise."
Echo	Radar return image.
Fade	Radar target image loses brightness or intensity.
False Target	Erroneous radar image caused by multipath, sidelobes, or other spurious noise data. (aka "Ghost")
FTC	Fast Time Constant radar control key, which filters rain clutter by restoring weak targets lost due to rain adjustment, reduces land echoes, thins out large targets.
GAIN	Radar adjustment which regulates signal amplification, adjusts display sensitivity. Once set, maintained at all ranges.
Ghost	See "False Target."
Interference	Radar noise resulting from two proximate and conflicting systems.
Knot(s)	Nautical Mile(s) (see "nm") per hour, used for wind speed.
Land Return	Radar interference from surface irregularities (e.g., waving grass, flocks of starlings) which causes "Clutter."
Masking	The intentional covering of sectors of airport surface maps with overlays (masks) in order to block unwanted radar returns view on the display screen.
Multipath	Multiple radar returns, both direct and indirect (reflected off objects) which cause amplitude fluctuations and Doppler spreading.
Noise	Randomly generated (or received) radar transmissions.
North Up	Radar screen orientation: top of screen is in true North direction.
Offset	Function to increase field of view of runway ends without use of longer range settings. When selected, radar screen blanks and rebuilds in 3 antenna scans.
RAIN	Radar control key which suppresses undesirable clutter returns from signals reflected from rain drops into light speckle at dim level.
Range	Scope of screen radar, on scale of: ¼, ½, ¾, 1, 1¼, or 1½ nm.
Return	Radar image, resulting from noise, land targets, etc.
Shadowing	An area of antenna sweep, partially obstructed by a building or other object, which causes reduced beam intensity.
Side Lobe	Any RF energy of a transmitted pulse falling outside narrow beam.
Split	Radar target image splits into two or more targets moving parallel.
Standard	A digital video processing technique (aka, Scan To Scan Integration) requiring three complete antenna scans in order to paint "build up" or "decay" of detected targets: 1 = dim, 2 = "mid", and 3 = bright. Lost targets likewise fade in three scans. Operators must keep in mind that 3 complete scans are needed to observe the results of 1 adjustment.
STC	Sensitivity Time Control radar adjustment, giving even clutter suppression, ideally reducing moving grass returns to a light speckle.
Storm Return	Image appearing as mass of small echoes, shifting in size, intensity, and location. Controlled by adjusting Rain.
Tune	Control of receiver frequency to match that of transmitter. Done manually in Phase I, tuning in Phase II is done by AFC.
View Up	Radar screen orientation: top of screen is view out tower window.

APPENDIX H

ACRONYM LIST

NOTE:	Acronyms mentioned only once in the text are omitted from this list.
AF	Airways Facilities
AFC	Automatic Frequency Control
AGL	Above Ground Level
AMASS	Airport Movement Area Safety System
ASDE	Airport Surface Detection Equipment, surveillance radar
ASDE-3	ASDE, Version 3
ASDE-X	ASDE, low-cost version
ASR	Airport Surveillance Radar
AT	Air Traffic
ATC	Air Traffic Control(ler) ("controller")
ATCT	Air Traffic Control Tower ("tower")
ATR	Aerospatiale/Alenia aircraft [ATC code]
B	Boeing aircraft [ATC code]
BA	British Airways aircraft [ATC code]
BE	Beechcraft aircraft [ATC code]
BRA-P	Braking Poor [Surface Conditions]
C	Cessna aircraft [ATC code]
CFAR	Constant False Alarm Rate
CL	Challenger aircraft [ATC code]
COTS	Commercial Off-The-Shelf
CW	Continuous Wave
dB	Decibel
dBm	Decibel, referenced to one milliwatt
DC	MacDonald Douglass aircraft [ATC code]
DGPS	Differential Global Positioning System
E	Brasilia aircraft [ATC code]
EBL	Electronic Bearing Line radar control key.
ELB	Electronic Line Bearing
ESD	Electrostatic Discharge
FAA	Federal Aviation Administration
FTC	Fast Time Constant radar control key
FTR	Fixed Target Reflector [surface to tower radio]
GPS	Global Positioning System
GCF	Ground Control Frequency
HOU	General William Hobby International Airport (Houston, TX)
IF	Intermediate Frequency
IR	Interference Rejection
kt	Knot(s) nautical mile(s) per hour
LCL	Local Time, as opposed to Zulu Time (Z, or Greenwich Time)
LED	Light Emitting Diode
LLC	Low-Loss [Radio Frequency] Cable
LLWAS	Low-Level Windshear Alert System
LNA	Low-Noise Amplifier
LR	LACSA aircraft [ATC code]
LRU	Line Replaceable Unit
LSR	Loose Snow on Runway [Surface Conditions]
MD	MacDonald Douglass aircraft [ATC code]
MDS	Minimum Discernible Signal

METAR	[FAA Aviation Code for] Aviation Routine Weather Report
MKE	General Mitchell International Airport (Milwaukee, WI)
MSL	Mean Seal Level
MTI	Moving Target Indicator (radar control)
MTR	Modulator Transmitter/Receiver ("transceiver")
μsec	Microsecond(s)
NAS	National Airspace System
NATCA	National Air Traffic Controllers Association
nm	Nautical Mile(s), 6076 feet, or 1.15 statute (standard) miles
NOP	Not Operating
NOTAM	Notice to Airmen [Surface Conditions]
nsec	Nanosecond(s)
OP	Operating
PDP	Power Distribution Panel
PSR	Packed Snow on Runway [Surface Conditions]
PRF	Pulse Repetition Frequency
RIRP	Runway Incursion Reduction Program
RF	Radio Frequency
RSEC	Radio Spectrum Engineering Criteria
RVR	Runway Visual Range
Rwy	Runway
SIR	Slippery Ice on Runway [Surface Conditions]
sm	Statute mile(s) (5,280 feet)
SOW	Statement of Work
TIM	Technical Interchange Meeting
TOP(s)	Target(s) Of Opportunity
Twy	Taxiway
UTC	Universal Time Code
VAC	Voltage, Alternating Current
VLSI	Very Large Scale Integration
Volpe	John A. Volpe Transportation Systems Center (Cambridge, MA)
VSWR	Voltage Standing Wave Ratio
WW	Westwind aircraft [ATC code]

APPENDIX I

BIBLIOGRAPHY

The listed documents have been consulted in the preparation of the current report. When they have occasionally been directly referenced herein, the short form of the title on the left has been noted.

Barton & Cook	Radar Evaluation Handbook, by David K. Barton, Charles E. Cook, and Paul Hamilton, editors, and staff of ANRO Engineering, Artech House, Boston (Norwood) MA, 1991.
FAA AASI	Federal Aviation Administration, Safety Data Services Division: Aviation System Indicators: 1996 Annual Report.
FAA ASSH	Federal Aviation Administration, Safety Data Services Division: Aviation Safety Statistical Handbook: 1996 Annual Report.
Maint Proc	Periodic and Preventive Maintenance Manual for Raytheon's Low-Cost Airport Surface Detection Equipment (ASDE-X) Ground Radar System, Installed at the Milwaukee WI General Mitchell International Airport, July 1997.
MKE I Report	Low-Cost ASDE Evaluation Report: Raytheon Marine (Phase I) Radar at MKE (ARPA M3450 / 18CPX-19), Volumes I & II. [DOT-FAA-ND410-96/1, July 1996].
Raytheon	Airport Surveillance Detection Equipment (ASDE) System: Technical Manual, Volumes 1 & 2. [G623-294 Rev A, December 1995].
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